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LOVELL'S SERIES OF SCHOOL BOOKS.

STUDENT'S NOTE BOOK

ON

INORGANIC CHEMISTRY,

INCLUDING BRIEF NOTICES OF THE

PROPERTIES, PREPARATION, AND CHEMICAL REACTIONS

OF THE

Principal Elements and their Compounds.

BY

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STUDENTS' NOTE BOOK

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PREFACE TO THE FIRST EDITION.

The sole object of the following compilation is to present to the Student the principal facts of Chemistry in so condensed a form as to obviate the necessity in a very great measure of his writing notes on the subject. It is simply intended to serve him as an "aide memoire" in Inorganic Chemistry, and not at all to supersede the ordinary textbooks on the science. A list of standard works on the various departments of chemical science is given at the end of the volume; and to some of these the student must of course apply himself for any detailed information upon methods of procedure, theoretical discussions, and notices of the innumerable less important chemical compounds. The older nomenclature is observed throughout, as being that generally met with, and least likely to present difficulties to the student.

TORONTO, August, 1862.

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... to gravitate all around you, unceasingly, insomuch that out of infinite possibilities, here and there, but now and again, certain laws are brought out more clearly, giving new strength to thoughts and principles of even greater interest, better suited to mankind; and yet

C H E M I S T R Y.

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LECTURE I.

DEFINITIONS AND NOMENCLATURE.

1. Chemistry is the science which investigates the nature, properties, and mutual relations of the various elements that enter into the composition of the different bodies with which we are acquainted ; or Chemistry may be defined to be the science which teaches us the mode of resolving a compound body into its elementary constituents, and of combining two or more elementary bodies into a compound.

2. Chemistry is divided into two branches :

- 1st. Inorganic Chemistry.
- 2nd. Organic Chemistry.

3. Inorganic Chemistry is that department of Chemistry which treats of the simple elements that enter into the composition of all known bodies, and of the chemical compounds formed by their union.

4. Organic Chemistry treats of the peculiar compounds into which the living plant or animal converts the ultimate elements of its food, and of the substances that enter into the structure of organized beings.

NOMENCLATURE.

5. Chemical Nomenclature was, before the discovery of oxygen, very loose and complicated, substances receiving the most trivial names.

Thus Sulphate of Magnesia was called Epsom Salts, from the Springs of Epsom ; Sulphate of Soda was called Glauber's Salts, from its discoverer, &c.

6. The Nomenclature at present in use was constructed by Lavoisier and his associates, towards the end of last century.

NOMENCLATURE.

7. All natural bodies are divided into two classes :

- 1st. Elementary or Simple Bodies. { *Metals*
- 2nd. Compound Bodies. { *Metalloids*

8. An element or elementary body is a body which, in the present state of the science, is incapable of being resolved, by chemical analysis or other means, into two or more dissimilar bodies.

9. A Compound body is a body resulting from the union of two or more elements.

10. The Elements at present recognized number 65, of which 13 are called Metalloids, and the remaining 52, Metals.

NOTE.—The number is somewhat uncertain, some chemists admitting only 62.

11. The 13 Metalloids, with their symbols, are as follows :

Element.	Symbol.	Combining number.	Element.	Symbol.	Combining number.
Oxygen.....	O	8	Silicon.....	Si	21.3
Hydrogen.....	H	1	Iodine.....	I	127
Nitrogen.....	N	14	Boron.....	B	11
Carbon.....	C	6	Brómine.....	Br	80
Sulphur.....	S	16	Flúorine.....	F	19
Chlorine.....	Cl	35.5	Selenium.....	Se	40
Phosphorus.....	P	32			

12. The 52 Metals, with their symbols and combining numbers, are as follows :

Alloys and Amalgams

NOMENCLATURE.

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follows:

Symbol.	Combining number.
Si	21.3
I	127
B	11
Br	80
F	19
Se	40

Element.	Symbol.	Combining Number.	Element.	Symbol.	Combining Number.
Aluminum.....	Al	13.7	Molybdenum.....	Mo	48
Antimony (Stibium)....	Sb	129	Nickel.....	Ni	29.5
Arsenic.....	As	75	Niobium.....	.....	.....
Aridium.....	Ar	.....	Norium.....	No	.....
Barium.....	Ba	69	Osmium.....	Os	99.5
Bismuth.....	Bi	71	Palladium.....	Pd	53
Cadmium.....	Cd	56	Pelopium.....	.....	.....
Calcium.....	Ca	20	Platinum.....	Pt	98.5
Cerium.....	Ce	46	Potassium (Kalium)....	K	39
Chromium.....	Cr	28	Rhodium.....	R	52
Cobalt.....	Co	30	Ruthenium.....	Ru	52
Copper (Cuprum)....	Cu	32	Silver (Argentum)....	Ag	108
Didymium.....	D	50	Sodium (Natrium)....	Na	23
Donarium.....	Do	80	Strontium.....	Sr	44
Erbium.....	E	.....	Tantalum or Columbium	Ta	92
Glucinum.....	Gl	26.5	Tellurium.....	Te	68
Gold (Aurum).....	Au	98.5	Terbium.....	Tb	.....
Iridium.....	Ir	99	Thorium.....	Th	59.5
Iron (Ferrum).....	Fe	28	Tin (Stannum).....	Sn	59
Ilmenium.....	Il	60	Titanium.....	Ti	24
Lanthanum.....	Ln	48	Tungsten (Wolfram)....	W	95
Lead (Plumbum)....	Pb	104	Uranium.....	U	60
Lithium.....	Li	6.4	Vanadium.....	V	68.5
Magnesium.....	Mg	12.5	Yttrium.....	Y	32
Manganese.....	Ma	27.5	Zinc.....	Zn	32.5
Mercury(Hydrargyrum)	Hg	100	Zirconium.....	Zr	32.5

13. Those elements long known retain their common names.

EXAMPLES.—Gold, Silver, Tin, Iron, Lead, &c.

14. Those elements more recently discovered take a name indicative of some prominent property.

EXAMPLES.—Chlorine from *chloros*, “green,” in allusion to its color.

Iodine from *ion*, a “violet,” and *eidos*, “resemblance,” from its violet-colored fumes.

Bromine from *bromos*, “fœtor,” referring to its intensely disagreeable odor.

NOMENCLATURE.

Chromium from *chroma*, a "color," in allusion to the brilliant colors of its compounds.

Glucinum from *glukus*, "sweet," its compounds being distinguished by a sweetish taste.

Oxygen from *oxus*, "acid," and *gennao*, "I generate or produce."

Hydrogen from *hudor*, "water," and *gennao*, &c.

x 15. Compound Bodies may be divided into—

1st. Acids. *Oxy-acids*

2nd. Bases. *Hydrosids*

3rd. Salts. *Neutral, e.g. selen, stann, etc.*

x 16. Acids have a sour taste, reddens vegetable blues, and neutralize alkalies. = *soluble bases*

x 17. Bases have an acrid taste, restore to blue the color reddened by an acid, and neutralize acids.

x 18. Salts are bodies arising from the union of acids with bases.

x 19. Salts are divided into three classes :

1st. Neutral Salts, or those in which neither the acid nor the base predominates.

2nd. Acid Salts or Super Salts, or those in which the acid is in excess.

3rd. Basic Salts or Sub-Salts, or those in which the base is in excess.

x 20. Acids prefix *per*, *hyper*, and *hypo*, and affix *-ic* and *-ous*.

x 21. Of the first element named in the compound,—except in case of the compounds of oxygen, when they always refer to the O,—*per* or *hyper* means more than *-ic*, and *-ic* more than *-ous*, while *hypo* implies less than *-ic* or *-ous* respectively.

Thus the compounds of oxygen and chlorine are named as follows :—

Perchloric acid or Hyperchloric acid = ClO_7 , i. e. a compound of seven equivalents of O to one of Cl.

Chloric acid = ClO_5 , i. e. a compound of five equivalents of O to one of Cl.

Hypochloric acid = ClO_4 , i. e. a compound of four equivalents of O to one of Cl.

NOMENCLATURE.

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Chlorous acid = ClO_3 , i. e. a compound of three equivalents of O to one of Cl.

Hypochlorous acid = ClO , i. e. a compound of one equivalent of O to one of Cl.

22. **Bases affix-ide.** It was formerly the custom to limit the affix-ide to binaries of which the first element named was oxygen or a metalloid ending in -ine, as chlorine, bromine, iodine, &c., and to apply the affix-uret in all other cases. This is, however, now falling into disuse, and the affix-ide is used for all bases except certain oxides in which the affix-a stands for the word oxide.

EXAMPLES.— Potassa = oxide of K; Soda = oxide of Na; Silica = oxide of Si; Alumina = oxide of Al; Magnesia = oxide of Mg, &c.

23. Salts formed from acids in -ic end in -ate.

EXAMPLES.— Sulphuric acid and soda unite to form sulphate of soda.

Nitric acid and potash unite to form nitrate of potash.

Acetic acid and lime unite to form acetate of lime.

Chloric acid and potash unite to form chlorate of potash, &c.

24. Salts formed from acids in -ous end in -ite.

EXAMPLES.— Sulphurous acid and soda unite to form sulphite of soda.

Chlorous acid and potash unite to form chlorite of potash.

Phosphorous acid and potash unite to form phosphite of potash.

25. Salts formed from acids in per, hyper, or hypo, always retain the per, hyper, or hypo.

EXAMPLES.— Hypophosphorous acid and potash unite to form hypophosphate of potash.

Hypochlorous acid and potash unite to form hypochlorite of potash.

Hypsulphurous acid and soda unite to form hypersulphite of soda.

NOMENCLATURE.

Perchloric acid and potash unite to form perchlorate of potash.

Permanganic acid and potash unite to form permanganate of potash.

- × 26. When a body is capable of forming two or more compounds with oxygen or another body, these compounds are distinguished from each other by the prefixes *Proto*, *Bi* or *Deuto*, *Tero* or *Trito*, and *Sesqui*, which always refer to oxygen if it be present; if not, to the first element named.

PROTO = 1.

EXAMPLES.—*Protioxide of Iron* = FeO = one equivalent of *O* to one of *Fe*.

Protosulphide of Mercury = HgS = one equivalent of *S* to one of *Hg*.

Protochloride of Copper = $CuCl$ = one equivalent of *Cl* to one of *Cu*.

DEUTO or BI = 2.

EXAMPLES.—*Binoxide of Manganese* = MnO_2 = two equivalents of *O* to one of *Mn*.

Bicarbonate of Soda = NaO_2CO_3 = two equivalents of Carbonic Acid to one of Soda.

Bichloride of Mercury = $HgCl_2$ = two equivalents of *Cl* to one of *Hg*.

Deutoxide of Hydrogen = HO_2 = two equivalents of *O* to one of *H*.

TRITO or TER = 3.

EXAMPLES.—*Tersulphide of Potassium* = K_3S = three equivalents of *S* to one of *K*.

Teroxide of Antimony = SbO_3 = three equivalents of *O* to one of *Sb*.

Sesqui = 3:2.

EXAMPLES.—*Sesquioxide of Manganese* = Mn_2O_3 = three equivalents of *O* to two of *Mn*.

Sesquisulphide of Chromium = Cr_2S_3 = three equivalents of *S* to two of *Cr*.

Sesquichloride of Aluminum = Al_2Cl_3 = three equivalents of *Cl* and two of *Al*.

✗ 27. Binary Compounds are such as result from the union of two simple elements.

EXAMPLES.—Bisulphide of Iron, FeS_2 ; Water, HO ; Sulphuric Acid, SO_3 ; Oxide of Phosphorus, P_2O ; Chloride of Sodium, $NaCl$, &c.

✗ 28. Ternary Compounds are such as result from the union of two binary compounds.

EXAMPLES.—Sulphate of Soda, Na_2SO_4 ; Carbonate of Lime, $CaCO_3$; and generally all bodies formed by the union of an acid with a base, or, in other words, all salts.

✗ 29. Quaternary Compounds result from the union of two ternary compounds, or, in other words, of two salts.

EXAMPLE.—Alum, which is $KO_2 \cdot SO_4 \cdot Al_2O_3 \cdot 2SO_4 \cdot HO$.

✗ 30. Radicals are those bodies which are capable of chemically uniting with one another, and are divided into—

1st. Simple Radicals.

2nd. Compound Radicals.

✗ 31. The Simple Radicals are the simple elementary bodies, as Oxygen, Hydrogen, Carbon, Sulphur, &c.

✗ 32. A Compound Radical is a chemical compound which, although containing two or more elements, enters into combination with elementary bodies, as though it were itself elementary; or a compound radical may be defined to be a compound substance which can be made to take the place of a simple element in certain chemical combinations.

As examples of compound radicals, the following may be given:—

✗ Cyanogen, C_2N

✗ Carbonic Oxide, CO_2

✗ Ethyle, C_2H_5

✗ Benzoyl, $C_6H_5O_2$

✗ Ammonium, NH_4

Mellone, C_6N_4

Acetylo, C_4H_3

Methyle, C_2H_3

Salicyle, $C_6H_5O_2$

Kakodylo, C_4H_6As

✗ 33. When a compound body is decomposed by galvanic electricity, those elements that go to the positive pole are termed electro-negative, and those that proceed to the negative pole are called electro-positive bodies.

We write the electro-positive body first in formulas.

LECTURE II.

LAWS OF COMBINATION.

I. Law of Fixed Proportions; II. Law of Multiple Proportions; III. Law of Equivalent Proportions; IV. Law of Combining Number of Compounds—Symbols—Combining Numbers—Chemical Notation—Relation between the Atomic Weights, Specific Gravities, and Combining Volumes of those Elements that exist in a Gaseous State.

LAWS OF CHEMICAL COMBINATION.

* 34. FIRST LAW.—All chemical compounds are definite in their nature, the ratio of the elements being constant.

35. This law is the result of chemical analysis, and is proved by synthesis.

EXAMPLE.—9 grains of water = one grain of H and eight grains of O; also 8 grains of O and 1 grain of H produce 9 grains of water.

36. The converse of this law is far from being true: the same elements combined in the same proportions do not of necessity generate the same substance.

EXAMPLE.—Oil of roses and illuminating gas are identical in chemical composition; as also are spirits of turpentine, oil of lemons, oil of juniper, oil of black pepper, and oil of bergamot.

* 37. SECOND LAW.—When a body is capable of combining with another in several proportions, these proportions bear a simple numerical relation to each other.

Thus, if A and B represent the two bodies that unite, their compounds will be as follows:

FIRST SERIES.

$A+B$	1st compound	$B = 1$
$A+BB$	2nd "	$B = 2$
$A+BBB$	3rd "	$B = 3$
$A+BBBB$	4th "	$B = 4$
$A+BBBBB$	5th "	$B = 5$

EXAMPLE.—In the compounds of *N* and *O* we have—

1st. NO or 14 grs. of <i>N</i> unite with 8 grs. of <i>O</i>	
2nd. NO_2 or 14 " " <i>N</i> 16 " <i>O</i>	
3rd. NO_3 or 14 " " <i>N</i> 24 " <i>O</i>	
4th. NO_4 or 14 " " <i>N</i> 32 " <i>O</i>	
5th. NO_5 or 14 " " <i>N</i> 40 " <i>O</i>	

SECOND SERIES.

$A+BBB$	1st compound <i>A</i> : <i>B</i> :: 1 :
$A+BBBBB$	2nd " " <i>A</i> : <i>B</i> :: 1 :
$A+BBBBBBB$	3rd " " <i>A</i> : <i>B</i> :: 1 : 7

EXAMPLE.—In the compounds of Arsenic with Oxygen we have—

1st. AsO_3 or 75 grs. of <i>As</i> unite with 24 of <i>O</i> .
2nd. AsO_5 or 75 " of <i>As</i> " 40 of <i>O</i> .

Sometimes one or more members of a series are wanting, as in compounds of *Cl* and *O*, which are ClO , ClO_3 , ClO_4 , ClO_5 , and ClO_7 , in which ClO_2 and ClO_6 are wanting or do not exist.

38. THIRD LAW.—If a body, *A*, unite with other bodies *B*, *C*, *D*, the quantities of *B*, *C*, *D*, which unite with *A*, will represent in numbers the proportions in which they unite among themselves in case such union takes place.

ILLUSTRATION.—8 grs. of *O* unite with 1 gr. of *H*; or with 16 grs. of *S*; or with 14 grs. of *N*; or with 35.5 grs. of *Cl*. Then 1, 16, 14, and 35.5 are the chemical equivalents or combining numbers of *H*, *S*, *N*, and *Cl*; that is, if any of these bodies unite to form a compound, the union always takes place in quantities proportional to these numbers.

EXAMPLE.—*H* and *Cl* unite to form HCl or hydrochloric acid, in which 1 gr. of *H* + 35.5 grs. of *Cl* = 36.5 grs. of HCl .

The number 35.5 is called the chemical equivalent of *Cl*, because that many grains of *Cl* go as far as 8 grains of *O* in saturating any amount of *H*, &c.

39. Chemical Equivalents are likewise called Combining Numbers and Atomic Weights.

40. The following are the Symbols and Combining Numbers

Multiple Proportions;
Law of Combining
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of *H* and eight
of *H* produce 9

g true: the same
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s are identical in
turpentine, oil of
oil of bergamot.

f combining with
as bear a simple

that unite, their

.. *B* = 1
.. *B* = 2
.. *B* = 3
.. *B* = 4
.. *B* = 5

of the principal elements.* It is necessary to remember that *H* stands not only for Hydrogen, but for one equivalent of it; *S* represents one equivalent of Sulphur; *K* one equivalent of Potassium, &c.

Elements. Metalloids.	Symbols.	Comb. No.	Elements. Metals.	Symbols.	Comb. No.
Hydrogen.....	H	1	Potassium.....	K	39.1
Oxygen.....	O	8	Sodium.....	Na	23
Nitrogen.....	N	14	Calcium.....	Ca	20
Carbon.....	C	6	Aluminum.....	Al	13.7
Chlorine.....	Cl	35.5	Magnesium.....	Mg	12.5
Sulphur.....	S	16	Manganese.....	Mn	27.5
Phosphorus.....	P	33	Iron.....	Fe	28
Boron.....	B	11	Lead.....	Pb	104
Bromine.....	Br	80	Zinc.....	Zn	32.5
Fluorine.....	F	19	Copper.....	Cu	63
Iodine.....	I	127	Mercury.....	Hg	100
Silicon.....	Si	21.3	Silver.....	Ag	108
Selenium.....	Se	40	Gold.....	Au	98.5
			Platinum.....	Pt	98.5

41. **FOURTH LAW.**—The combining number of a compound is the sum of the combining numbers of its components.

42. This law follows as a necessary result of the law of equivalent proportions.

It is proved both by analysis and by synthesis. Thus, by synthesis—to saturate 47 parts by weight of Potassa, or 116 parts by weight of Oxide of Silver, there are required 40 parts of Sulphuric Acid, or 54 parts of Nitric Acid, or 75.5 parts of Chloric Acid, or 167 parts of Iodic Acid, or 51 parts of Acetic Acid.

* It was deemed advisable to give this table so that the student might have collected in small compass the symbols, combining numbers, &c., of the elements most commonly met with.

remember that
equivalent of it; S
is equivalent of

Symbols.	Comb. No.
K	39.1
Na	23
Ca	20
Al	13.7
Mg	12.5
Mn	27.5
Fe	28
Pb	104
Zn	32.5
Cu	32
Hg	100
Ag	108
Au	98.5
Pt	98.5

a compound is

of the law of

is. Thus, by
tassa, or 116
ired 40 parts
75.5 parts of
rts of Acetic

student might
numbers, &c., of

- Now 47 parts KO = one equivalent K , 39 + one equivalent O , 8 and 39 + 8
 $= 47$ = Combining Number of KO .
116 parts AgO = one equivalent Ag , 108 + one equivalent O , 8 and 108 + 8
 $= 116$ = Combining Number of AgO .
40 parts SO_3 = one equivalent S , 16 + three equivalents O , 24 and 16 + 24
 $= 40$ = Combining Number of SO_3 .
54 parts NO_5 = one equivalent N , 14 + five equivalents O , 40 and 40 + 14
 $= 54$ = Combining Number of NO_5 .
75.5 parts ClO_5 = one equivalent Cl , 35.5 + five equivalents O , 40 and 40
 $+ 35.5 = 75.5$ = Combining Number of ClO_5 .
167 parts IO_5 = one equivalent I , 127 + five equivalents O , 40 and 40 + 127
 $= 167$ = Combining Number of IO_5 .
51 parts Acetic Acid = four equivalents of C , 24 + three of H , 8 + three
of O , 24, and $24 + 8 + 24 = 51$ = Combining Number of Acetic Acid.

Thus the combining number of the compound is in every case equal to the sum of the combining numbers of its constituents.

The same may be proved by taking any acid and finding by experiment the amounts of different bases required to neutralize it.

43. When gases combine chemically, union invariably takes place either between equal volumes or between volumes which bear a simple relation to each other.

44. This is not only true of elementary gases, but also of compound gases and the vapors of volatile liquids, when they unite among themselves.

45. The ultimate reason of this law may be found in the very remarkable relation existing between the specific gravity of a body in a gaseous state and its chemical equivalent, viz.: Quantities by weight of the various gases which combine, occupy (temperature and pressure being equal) either equal volumes or volumes bearing a simple relation to each other.

Thus 8 grs. of O occupy (60° Fahr. and 30 in. Bar.) 23.3 cub. in.
1 " H " " " " 46.7 "
35.5 " Cl " " " 46.2 "
127 grs. vapor of I " " " 46.7 " "

That is, equivalents of H , Cl , and I occupy equal volumes,
and of O half a volume.

46. If both the specific gravity and the chemical equivalent of a gas be known, its equivalent or combining volume can

easily be determined, since it will be represented by the number of times the weight of a unit of volume (the spec. grav.) is contained in the weight of one chemical equivalent of the substance; i. e., the equivalent volume of an element is found by dividing its chemical equivalent by its specific gravity, and comparing the quotient with that obtained in the case of H.

Substance.	Sp.grav.	Equiv. weight.	Equivalent volume.
Hydrogen.....	0.0698.	1.0...	14.48 or 1
Nitrogen.....	0.972.	14.0...	14.87 or 1
Chlorine.....	2.470.	35.5...	14.88 or 1
Bromine Vapor.....	5.895.	80.0...	14.82 or 1
Iodine Vapor.....	8.716.	147.0...	14.57 or 1
Carbon Vapor.....	0.418.	6.0...	14.34 or 1
Mercury Vapor.....	7.000.	100.0...	14.29 or 1
Oxygen.....	1.106.	8.0...	7.28 or $\frac{1}{2}$
Phosphorous Vapor.....	4.350.	32.0...	7.85 or $\frac{1}{2}$
Arsenic Vapor.....	10.420.	75.0...	7.19 or $\frac{1}{2}$
Sulphur Vapor.....	6.654.	16.0...	2.40 or $\frac{1}{3}$
Water Vapor.....	0.625.	9.0...	14.40 or 1
Protodoxide of Nitrogen.....	1.525.	22.0...	14.48 or 1
Sulphuretted Hydrogen.....	1.171.	17.0...	14.51 or 1
Sulphurous Acid.....	2.210.	32.0...	14.52 or 1
Carbonic Oxide.....	0.973.	14.0...	14.39 or 1
Carbonic Acid.....	1.524.	22.0...	14.48 or 1
Light Carburetted Hydrogen.....	0.559.	8.0...	14.31 or 1
Olefiant Gas.....	0.981.	14.0...	14.27 or 1
Binoxide of Nitrogen.....	1.089.	30.0...	28.87 or 2
Hydrochloric Acid.....	1.269.	36.5...	28.70 or 2
Phosphoretted Hydrogen.....	1.240.	35.0...	28.22 or 2
Ammonia.....	0.589.	17.0...	28.86 or 2
Ether Vapor.....	2.586.	37.0...	14.31 or 1
Alcohol Vapor.....	1.618.	46.0...	28.52 or 2
Benzol Vapor.....	2.788.	78.0...	28.49 or 2

Thus it appears that *H*, *N*, *Cl*, *Br*, *I*, *C*, and *Hg*, in the state of vapor, have the same equivalent volume; *O*, *P*, *As*, one-half of this; *Sulphuric Acid*, one-sixth, &c.

NOTE.—The slight discrepancies in the third column result chiefly from errors in determining the specific gravities.

ES.

ed by the number
ec. grav.) is con-
of the substance;
and by dividing its
d comparing the

Equivalent volume.
14.48 or 1
14.87 or 1
14.88 or 1
14.82 or 1
14.67 or 1
14.84 or 1
14.29 or 1
7.28 or $\frac{1}{2}$
7.85 or $\frac{1}{2}$
7.19 or $\frac{1}{2}$
2.40 or $\frac{1}{3}$
14.40 or 1
14.48 or 1
14.51 or 1
14.52 or 1
14.89 or 1
14.42 or 1
14.81 or 1
14.27 or 1
28.87 or 2
28.70 or 2
28.22 or 2
28.86 or 2
14.31 or 1
28.52 or 2
28.49 or 2

Hg, in the state
 P , As , one-half
result chiefly from

NOTATION.

17

NOTATION.

47. The symbol of an element standing alone signifies 1 atom or equivalent of the element.

Thus H stands for 1 atom or equivalent of Hydrogen, Fe for 1 atom of Iron, &c.

48. A symbol with a small figure below and to the right of it, signifies as many atoms of the element as the figure expresses.

Thus O_2 means two equivalents of O ; S_5 means five of sulphur, &c.

49. Symbols joined by the sign +, or simply placed together, signify a compound of 1 atom of each element. Thus $H+O$ or HO = Water, a compound of 1 atom of H and 1 of O .

50. If a small figure be attached, as above, to either or both symbols, it multiplies that symbol only to which it is attached.

Thus MnO_2 = Binoxide of Mn = 1 equivalent of Mn and 2 equivalents of O . So also Fe_2O_3 = Sesquioxide of Iron = 2 equivalents of Fe and 3 equivalents of O , &c.

51. When a compound formed by the union of two or more compounds is to be expressed, the compounds which combine are joined either by the sign + or by a comma.

Thus $HO+SO_3$ or HO,SO_3 signifies Hydrated Sulphuric Acid = 1 equivalent of water and 1 equivalent of dry SO_3 .

52. A large figure placed on the same level as the symbol, and to the left of it, multiplies every symbol as far as the next comma or next + sign; or it multiplies all within brackets if placed before them.

Thus $2HO$ = 2 equivalents of Water = $2H+2O$; $2SO_3, KO, HO$ = Bisulphate of Potash = 2 equivalents of SO_3 , 1 equivalent of KO and 1 equivalent of HO . But $2(SO_3, KO, HO)$ or $2(SO_3+KO+HO)$ = 2 equivalents of a compound which is formed of 1 equivalent of SO_3 , 1 equivalent of KO , and 1 equivalent of HO .

53. The following are some examples of chemical formulas :

Alum	$= Al_2O_3 \cdot 3SO_3 + KO_3 \cdot SO_3 + 24H_2O$.
Sugar	$= C_{12}H_{22}O_{10}$.
Alcohol	$= C_2H_5O_2$.
Acetic Acid	$= C_2H_4O_2 + HO$.
Morphine	$= C_{21}H_{34}NO_6$.
Acetate of Morphine	$= C_{21}H_{34}NO_6 \cdot C_2H_5O_2$.

54. Sometimes, in order to show the new arrangement of the elements in chemical combinations, we make use of the equation. Thus, $KO + HCl = HO + KCl$.

LECTURE III.

CHEMICAL AFFINITY.

55. Elements which are capable of chemically uniting are said to have an *affinity* for each other.

This power of union or affinity is exceedingly different in degree among various bodies, and is much modified by a number of circumstances.

56. As a general rule, the more unlike any two bodies are in chemical properties the stronger is their affinity for each other. Thus the metals have a strong affinity for oxygen and chlorine; the bases, a strong affinity for acids, &c.

57. Chemical Affinity may be defined to be that force or attraction by which the particles of two or more dissimilar bodies unite to form a compound which is totally different in its chemical nature from either of its constituents.

+ 58. Affinity is either simple or elective.

59. Simple Affinity is that force by which two or more *free* bodies become chemically united.

EXAMPLES OF SIMPLE AFFINITY.

1. Sulphur } = Sulphuric Acid. 2. Sulphur } = Vermilion.
Oxygen } Mercury }

3
5
i. e.
con
Ace
Zinc
Acet
L
Sulph
C
Ammon
Sulph
C
Iron

CHEMICAL AFFINITY.

19

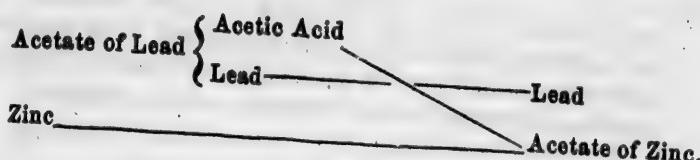
3. Oxygen } = Water. 4. Chlorine } ^{Sodium chloride}
 Hydrogen Sodium Common Salt. No 61
 5. Oil } = Soap. 6. Oxygen }
 Potash Hydrogen Carbon Sugar.

60. Elective Affinity is either single or double.

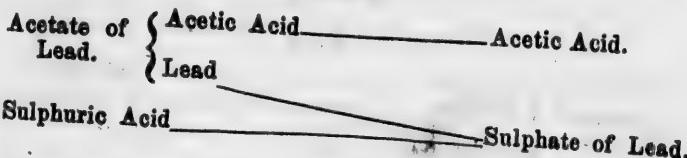
61. Single Elective Affinity involves a single decomposition; i. e., it enables a body, *A*, to elect or choose another, *B*, which is combined with a third, *C*, which third, *C*, is always set free.

EXAMPLES OF SINGLE ELECTIVE AFFINITY.

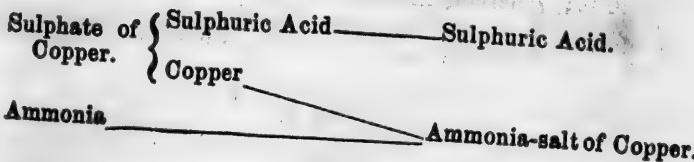
No. 1.



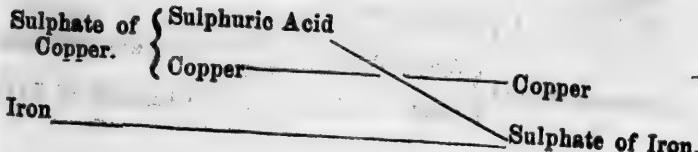
No. 2.



No. 3.



No. 4.



No. 5.



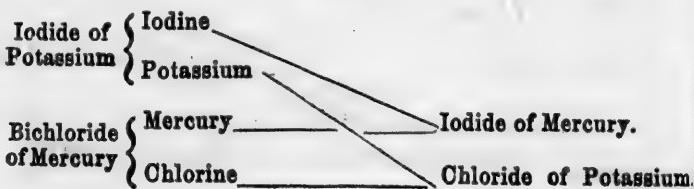
No. 6.



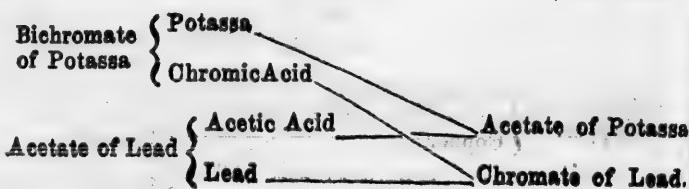
63. Double Elective Affinity involves a double decomposition; i. e., when two compounds are placed together under favorable circumstances, they are both decomposed, and their constituents re-unite and form two new and entirely distinct compounds.

EXAMPLES OF DOUBLE ELECTIVE AFFINITY.

No. 1.



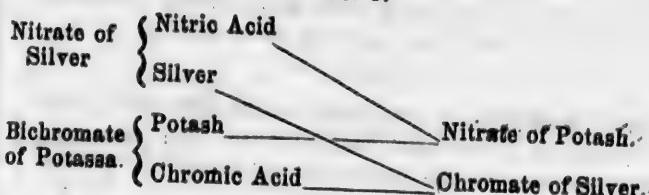
No. 2.

Nitra
SilvBichr
of Po

63.

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2.X 64.
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lumps
other;
comme65. S
atoms oCarbo
to unite
solution66. H
means oSilica
Sulphu
bine with
is melted

No. 3.



63. Solution is the result of feeble affinity.

EXAMPLES.

1. *Alcohol* dissolves *camphor*, but not *gum*.
2. *Water* dissolves *gum*, but not *camphor*.

64. Chemical affinity exists only between unlike particles and at insensible distances. Hence the more finely substances are comminuted, the more readily chemical union takes place.

EXAMPLE.

Dry Sal-Ammoniac and *Dry Lime*, when placed in contact in lumps or masses, exhibit but little tendency to act on one another; but when both are pulverized, chemical action at once commences, and Ammoniacal Gas is evolved.

65. Solution greatly promotes chemical union by bringing the atoms of the constituents into contact.

EXAMPLE.

Carbonate of Soda and *Tartaric Acid* exhibit no disposition to unite when in a dry state, but combine readily when in solution.

66. Heat favors chemical union, being in fact a most powerful means of solution.

EXAMPLES.

Silica and *Potash* unite by strong heat, and form glass.

Sulphur will not unite with cold *Iron*, but will readily combine with it either when the iron is red hot, or when the sulphur is melted.

67. Bodies in the nascent state as it is called, (*nascens*, "being born,") will often unite when under ordinary circumstances no affinity is manifested between them.

EXAMPLE.

Hydrogen and *Nitrogen*, when mingled in the same vessel, will not unite, but are constantly combining to form ammonia, when they are both in the process of being set free by the decomposition of organic substances.

68. The presence of a third body often causes a union, or the exertion of affinity, when this third body takes no part in the change which occurs, this third body is said to act by —

EXAMPLE. Catalysis.

Oxygen and *Hydrogen*, when mingled in the same vessel, do not combine, but at once unite in presence of spongy platinum.

× 69. The most striking phenomena which accompany chemical affinity are—

I. Evolution of Light :—

EXAMPLE.

If a piece of metallic *Potassium* be thrown on water, so great is its affinity for *O* that it decomposes the water, uniting with the *O* and setting fire to the *H*.

II. Evolution of Heat :—

EXAMPLES.

Sulphuric Acid mixed with *Water*.

Sulphuric Acid poured upon a saturated solution of *Loaf Sugar* produces sufficient heat to evaporate the water.

III. Evolution of Electricity :—

EXAMPLES.

All Voltaic combinations.

IV. Change of Color :—

EXAMPLES.

Solutions of Iodide of Potash and Dichloride of Mercury, both of which are colorless odorous, when mixed together, a brilliant scarlet.

If water be colored by tincture of cabbage—Liquid Ammonia at the top turns it green, and Sulphuric Acid at the bottom turns it red.

V. Change of Volume:—

EXAMPLES.

Water and Alcohol.

Water and Sulphuric Acid.

VI. Change of Form:—

EXAMPLES.

Hydrochloric Acid Gas and Ammoniacal Gas—two gases form a solid.

Sulphuric Acid and Chloride of Lime—two fluids form a solid.

Chloride of Calcium and Carbonate of Potash—two fluids form a solid.

Caustic Potash and Sulphate of Magnesia—two fluids form a solid.

Sulphuric Acid and saturated Solution of Sugar—two fluids form a solid.

Amalgam of Lead and Amalgam of Bismuth—two solid metals form a fluid.

Acetate of Lead and Sulphate of Zinc—two solids produce a fluid.

Sulphate of Soda and Carbonate of Potash—two solids form a fluid.

Sulphate of Soda and Nitrate of Ammonia—two solids form a fluid.

Sulphuric Acid and Alcohol—two fluids give rise to an inflammable gas.

Spirits of Turpentine and Aqua Regia—two fluids give rise to a spontaneously inflammable gas.

Sulphuric Acid and a mixture of Potassa and Loaf Sugar—a liquid and a solid give rise to spontaneous combustion.

Water and dry Phosphate of Soda produce a spontaneously inflammable gas.

- Ether and Chlorate of Potash moistened with Sulphuric Acid produce a spontaneously inflammable gas.
- Sulphur and Chlorate of Potash detonate when cautiously rubbed together in small quantities in a mortar.
- Sulphur and Chlorate of Potash thrown on Sulphuric Acid produce an explosion and flame.
- Lime and Sal-Ammoniac—two solids produce a gas.

LECTURE IV.

ATOMIC THEORY, CRYSTALLIZATION, ISOMORPHISM, ISOMERISM, ALLOTROPISM.

ATOMIC THEORY.—*Daltonian*

70. The Atomic Theory of the constitution of matter assumes that matter is not infinitely divisible, but is ultimately composed of minute indivisible particles, which are termed *atoms*.

71. These atoms are supposed to be of different weights in different bodies, and probably of different magnitudes. They are also supposed to be spherical, perfectly hard, opaque, and destitute of color.

72. When bodies combine chemically, their union must be so effected that one atom of the one unites with one atom of another, or one atom of the one unites with two, three, or four of another; or two atoms of the first with three, five, or seven atoms of the second; but no intermediate degree can occur, since the atom is absolutely indivisible.

73. The relative weights of these atoms are the equivalent numbers of the bodies combined.

74. The following is an illustration of the mode in which the Atomic Theory is applied to the explanation of the laws of chemical combination.

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Law of Definite Proportions.—Eight parts by weight of oxygen combine with one of hydrogen to form water; because the simplest proportion in which they can unite is one atom of each, and one atom of *O* is eight times as heavy as one atom of *H*.

Law of Equivalent Proportions.—8 parts of *O* are equivalent to 35·5 of *Cl*; because when an atom of *H* leaves the atom of *O* it combines with an atom of *Cl*, and an atom of *Cl* is heavier than an atom of *O* in the proportion of 35·5 to 8.

Law of Multiple Proportions.—In the different combinations of *O* and *N*, the *O* amounts to 8, 16, 24, 32, or 40 parts of the compound by weight; because one atom of *N* unites with one atom of *O*, or with two atoms of *O*, or with three atoms of *O*, or with four atoms of *O*, or with five atoms of *O*.

Protoxide of Nitrogen.



Binoxide of Nitrogen.



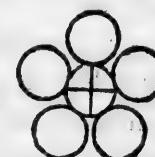
Nitrous Acid.



Hyponitric Acid.



Nitric Acid.



Law of Combining Number of Compounds.—Since an atom of water is compound, being composed of one atom of *O* and one atom of *H*, and since the atomic weights of *O* and *H* are 8 and 1, the atomic weight or combining number of water must, of necessity, be 9.

75. Thus the Atomic Theory explains all the fundamental laws of chemistry; nevertheless it is by no means established as a fixed law or principle in physical science. Some of our best chemists reject it altogether. Sir Robert Kane maintains that while every chemical phenomenon may be explained without a reference to it, many are totally irreconcilable with it unless greatly modified.

CRYSTALLIZATION.

76. When certain solid substances are dissolved in liquids or melted, so that their particles are free to move among each other, upon the evaporation of the liquid or on the cooling of the

melted mass the atoms arrange themselves together in certain regular geometrical forms called Crystals.

77. The process by which crystals are formed is termed Crystallization.

78. Bodies may be crystallized by *solution*, by *melting*, or by *sublimation*. Salt, Alum, Epsom Salts, and Iodide of Potassium, are good examples of crystallization by solution ; Sulphur, Zinc, and Bismuth, are good examples of crystallization by melting ; Arsenic, Arsenious Acid, Benzoic Acid, and Corrosive Sublimate, are good examples of crystallization by sublimation.

79. Some bodies may be crystallized by more than one of these processes. Thus Corrosive Sublimate may be crystallized by solution or by sublimation ; Sulphur, by fusion or by solution. It is remarkable that, when this occurs, the crystals obtained by the two processes are never of the same shape, but indicate a totally different mode of arrangement of particles.

80. A body which may be thus crystallized in two ways is said to be Dimorphous.

81. In cases where bodies are *dimorphous*, one form is generally unstable, and the body, when crystallized in it, passes after some time into the other form.

82. The more slowly the change of state occurs and the more regularly, the larger and finer are the crystals formed. In solutions, a little crystal of the same kind of salt is often introduced to serve as a nucleus round which the new crystals may gather ; and in a solution containing many salts, the nature of the salt which shall crystallize may be determined by the nature of the little crystal introduced. Thus if equal parts of Nitre and of Glauber's Salts be mixed and dissolved in five parts of water, and the solution divided between two similar vessels, on a crystal of nitre being laid in one vessel and a crystal of Glauber's salts in the other, a crystallization of pure nitre will occur in the former, while nothing but Glauber's salts will crystallize in the latter vessel.

83. Crystals occasionally form in a body although it may remain completely solid : Thus when copper wire has been kept

fusible & porous

a length of time in the laboratory it becomes a mass of cubical crystals, and its tenacity is almost completely lost. Blows, continued vibration, friction, and variations in temperature, produce changes in the molecular arrangement of metals; and it is thought that the axles of railroad cars, although at first constructed of tough and fibrous wrought-iron, may, from these causes, acquire that crystalline and brittle structure which they often exhibit when broken.

84. Crystals of the salts often contain water, called the *water of crystallization*. These, when exposed to the air or to heat, part with their water, lose their transparency, turn white, and fall to powder: this is called Efflorescence. Other crystals attract water from the air, and this is known as Deliquescence.

85. In all cases of crystallization there is heat evolved, consequent on the general law of heat being given out when a liquid or a vapor becomes solid.

86. Crystallization is sensibly affected by the presence or the absence of Light. If a dish half covered by paper be set aside with a solution to crystallize, but few crystals will form in the dark, although there may be an abundant crop in the illuminated portions of the vessel.

87. If a crystal of tolerably simple form be carefully examined, it will be found that certain directions can be pointed out in which straight lines may be imagined to be drawn passing through the centre of the crystal from side to side, or from end to end, or from one angle to that opposite to it, about which lines the particles of matter composing the crystal may be conceived to be symmetrically built up.

88. These lines are called *axes*; and upon their number, relative lengths, positions, and inclinations to each other, depends the outward figure of the crystal itself.

89. All crystalline forms may, upon this plan, be arranged in six classes or systems. These are as follows:

CRYSTALLIZATION.

I. THE REGULAR SYSTEM.

Three equal axes all placed at right angles to each other.

PRINCIPAL FORMS.—(1) Cube; (2) Regular Octahedron; (3) Rhombic Dodecahedron.

EXAMPLES.—This is the most abundant of all forms—Metals, Carbon (Diamond), Common Salt, Alums, Iodide of Potassium, Fluor-spar, &c.

II. THE SQUARE PRISMATIC SYSTEM.

Three axes at right angles to each other, but only two of equal length.

PRINCIPAL FORMS.—(1) Right Square Prism, and (2) Right Square-based Octahedron.

EXAMPLES.—Yellow Ferrocyanide of Potassium, Zircon, &c.

III. THE RIGHT PRISMATIC SYSTEM.

Three axes at right angles to each other, all of unequal length.

PRINCIPAL FORMS.—(1) Right Rectangular Prism; (2) Right Rhombic Prism; (3) Right Rectangular-based Octahedron; (4) Right Rhombic-based Octahedron.

EXAMPLES.—Nitrate and Sulphate of Potassa, Sulphate of Barytes, Arsenical Iron Pyrites, &c.

IV. OBLIQUE PRISMATIC SYSTEM.

Three axes which may all be unequal, two at right angles, and the third oblique to one and perpendicular to the other.

PRINCIPAL FORMS.—(1) Oblique Rectangular Prism; (2) Oblique Rhombic Prism; (3) Oblique Rectangular-based Octahedron; (4) Oblique Rhombic-based Octahedron.

EXAMPLES.—Sulphate, Carbonate, and Phosphate of Soda, Sulphur (by cooling from fusion), Realgar, Borax, Green Vitriol, &c.

V. DOUBLE OBLIQUE PRISMATIC SYSTEM.

Three axes which may all be of unequal lengths, and are all oblique to each other.

PRINCIPAL FORMS.—(1) Double Oblique Prism; (2) Double Oblique Octahedron.

EXAMPLES.—Sulphate of Copper, Nitrate of Bismuth, Quadroxalate of Potassa, &c.

VI. RHOMBOHEDRAL SYSTEM.

Four axes, three of which are equal, in the same plane, and inclined to each other at an angle of 60°, while the fourth or principal axis is perpendicular to all.

PRINCIPAL FORMS.—(1) Regular six-sided Prism; (2) The Quartz Dodecahedron; (3) Rhombohedron; (4) Scalene Dodecahedron.

EXAMPLES.—Ice, Calcareous Spar, Nitrate of Soda, Rock Crystal, Arsenic, Antimony.

NOTE.—The angles of crystals are measured by an instrument called a Goniometer.

ISOMORPHISM.

90. Certain bodies possess the very remarkable property of exactly replacing each other in crystallized compounds without alteration of the characteristic geometrical form. Thus, if a crystal of ordinary Alum be placed in a solution of Sulphate of Alumina and Ammonia, it increases in size, and still maintains its octahedral form; and if after a time it be placed in a solution of Ammonia and Peroxide of Iron, it acquires another layer, and increases still further in size. Such bodies are said to be *Isomorphous* or *Similiform* (from the Greek *isos*, "equal," and *morphe*, "form.")

ISOMERISM.

91. Isomeric compounds are such as contain the same elements in the same proportions, and yet possess different properties. Thus, Spirits of Turpentine, Oil of Lemons, Oil of Juniper, Oil of Black Pepper, and Oil of Bergamot, are identical in composition, as also are Oil of Roses and Illuminating Gas.

92. The difference of properties in isomeric bodies is accounted for by supposing that the atoms are differently arranged in the different cases.

* ALLOTROPISM.

93. Several of the elementary bodies exist in two or three distinct and totally incompatible forms. Thus Carbon is found as Diamond in transparent octahedrons, as Graphite in opaque black prisms, and as common charcoal, which is black and quite amorphous. Sulphur is found as a hard stony yellow substance, and as a brown viscid amorphous mass. Phosphorus is found as a white translucent readily inflammable substance, and as a deep reddish-brown, amorphous, dense mass much less inflammable. Oxygen also exists in two states. These are now called *allotropic forms* of the element (Greek *allō*, "another," and *tropos*, "character," "direction," i. e., atoms differently arranged, and hence producing a body of another character).

LECTURE V.

OXYGEN.

94. OXYGEN. Symbol *O*; Equiv. = 8; Comb. vol. $\frac{1}{2}$; Spec. Grav. 1.1057; 100 cubic inches weigh 34.2 grains.

95. Oxygen forms $\frac{1}{8}$ by weight of water, $\frac{1}{8}$ of the atmosphere, and at least $\frac{1}{2}$ of the solid crust of the earth.

96. Oxygen, when free, exists only in the form of a gas; it has never been reduced to the solid or the liquid form; is a permanently elastic invisible gas, without taste or smell.

97. Oxygen is the sustaining principle of animal life and of ordinary combustion.

98. Oxygen unites with all the other elements (Fluorine, perhaps, excepted), and with most of them in several proportions.

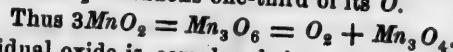
99. Water absorbs or dissolves about 4 per cent. of *O*; and it is upon this *O* that aquatic animals depend for their respiratory process.

100. Oxygen was discovered by Priestley in England, and by Scheele in Sweden simultaneously, in 1744. It was called Vital

Air from its being the sustaining principle of animal life; Scheele termed it Empyreal Air on account of its supporting combustion; Priestley called it Dephlogisticated Air,—i. e., common air deprived of its phlogiston, an imaginary inflammable element; Lavoisier called it Oxygen (*oxus*, “acid,” and *gennao*, “I produce”) from its being regarded as the essential acidifying principle of acids.

101. Oxygen may be prepared from Red Oxide of Mercury by the application of heat, the HgO being resolved into metallic Hg , 108 grains of HgO = 100 of Hg + 8 of O .

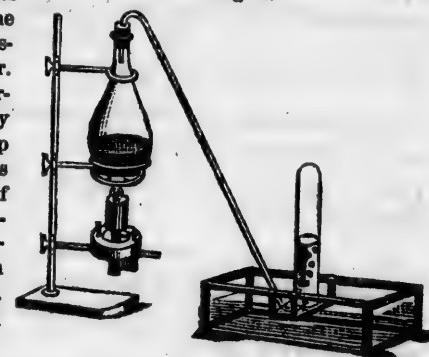
102. Oxygen may be prepared from the Bioxide of *Mn* (MnO_2) by the application of a red heat. When heated to redness, the MnO_2 abandons one-third of its O .



This residual oxide is complex, being a mixture of MnO and Mn_2O_3 . Thus, $Mn_3O_4 = MnO$ and Mn_2O_3 , i. e. protoxide and sesquioxide.

Pure MnO_2 = 27.5 of Mn + 16 of O , of which 5.3 of O are given off. ∴ 1 lb. Troy of pure MnO_2 will yield 700 grains of O = 2000 cubic inches = 7 gallons. In the MnO_2 of commerce

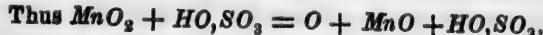
Fig. 1.



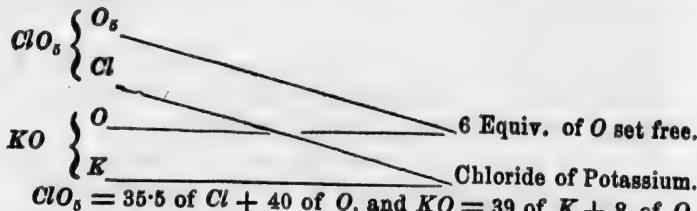
* Oxygen and many other gases are collected in the Pneumatic Trough by displacing water from a jar. In order to obtain moderately pure oxygen, apply the heat of a spirit-lamp to a mixture of 4 parts by weight of Chlorate of Potassa and 1 part of Bioxide of Manganese, contained in a flask, as seen in the accompanying figure. The bottle or jar which is to contain the gas is previously filled with water in the pneumatic trough, inverted under the water and carefully slid on the shelf, which must be beneath the surface of the water in the trough. After a few bubbles of gas have escaped, the end of the tube is placed under the mouth of the jar, and the gas, escaping in bubbles, rises in the jar and displaces the water. When the jar is filled it is carefully stoppered, and another prepared to receive the gas.

there is only 65 per cent. of pure Oxide, and hence the quantity of O obtained is only $= \frac{1}{3}$ of the above amount.

103. When MnO_2 is treated with HO, SO_3 (Sulphuric Acid) and heated, it yields one-half its O .



104. Very pure O may be obtained from Chlorate of Potassa (KO, ClO_5) by heating it in a flask to redness. The following is the reaction :



Hence 100 parts of KO, ClO_5 give 40 parts of O , or 1 oz. Troy gives 192 grains or 561 cubic inches of O .

$$\therefore 1 \text{ oz. of } KO, ClO_5 = 5 \text{ oz. of } MnO_2 \text{ as a source of } O.$$

105. In practice, O is most easily obtained from a mixture of 4 parts KO, ClO_5 , and 1 part MnO_2 . Here the heat required is less than one-half that necessary to decompose either the KO, ClO_5 or the MnO_2 alone. All the O comes from the KO, ClO_5 , the MnO_2 remaining unchanged.

106. In this case the MnO_2 appears to act by its mere presence, and is said to act by Catalysis or to produce Catalytic Action (*kata*, "against" or "by contact," and *luo*, "I loosen," i. e. to loosen by contact).

107. A very good mode of obtaining O is to heat Bichromate of Potash with excess of Sulphuric Acid. Thus $KO_2CrO_3 + 4(HO, SO_3) = KO, SO_3 + Cr_2O_3 + 3SO_3 + 4HO + O_3$, i. e. 3 equiv. of O are set free.

EXPERIMENTS.

- I. Introduce a glowing stick into a jar of O ; it instantly bursts into flame. Product Carbonic Acid = CO_2 .

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sulphuric Acid)
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of Potassium.
 $K + 8$ of O .
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sen," i. e. to
t Bichromate
 $O_2CrO_3 + 4$
 $+ O_3$, i. e. 3
it instantly

II. Introduce an extinguished taper, with glowing wick, into a jar of O ; it is re-kindled, and burns with great brilliancy. Product, Carbonic Acid.

III. Introduce a piece of charcoal into a jar of O ; it burns with exceeding energy. Product, Carbonic Acid.

IV. Introduce a piece of sulphur into a jar of O . Product, Sulphurous Acid.

V. Introduce a piece of phosphorus into a jar of O ; the light produced by the combustion is so intense that the eye cannot endure it. Product, Phosphoric Acid.

VI. Introduce a piece of coiled steel-wire into a jar of O . Product, Carbonic Acid and Oxide of Iron.

VII. Introduce a piece of ignited India-rubber. Product, Carbonic Acid and Water.

VIII. Introduce a mouse into a jar of O ; it becomes feverish and excited, but will live longer than in the same amount of common air.

IX. If a piece of prepared lime or chalk be placed in the flame of Hydrogen, and a jet of O be cast upon it, the light will be of the most dazzling brightness, rivalling even that of the sun. This is the celebrated Drummond Light.

108. Pure O is constantly supplied by the processes of vegetable life.

109. O exists in an *allotropic* or second form, and is then called Ozone (*ozo*, "I smell").

110. Ozone is produced by passing a series of electric sparks through dry O , or by leaving P for a long time under water in a closed bottle containing air. Ozone is the most powerful oxidizing agent known. It may be detected by its peculiar smell, or by prepared test-paper, i. e. paper steeped in a weak solution of Iodide of Potassium containing starch. The Ozone oxidizes the Potassium of the Iodide, and sets free the Iodine, which instantly blues the starch.

111. Compounds of *O* with other bodies are termed Oxides.

112. Oxides are divided into three classes.

I. Alkaline, or Basic Oxides, or Salifiable Bases.

II. Neutral or Indifferent Oxides.

III. Acid Oxides.

If *M* represents a metal or an electro-positive body, the basic oxides are constituted as follows:

MO =Protioxide, usually the most powerful base. Ex. KO ;
 CaO ; FeO ; MnO , &c.

M_2O_3 =Sesquioxide, a weaker base. Ex. Fe_2O_3 ; Al_2O_3 ;
 Mn_2O_3 , &c.

MO_2 =Deutoxide, a still weaker base. Ex. PbO_2 ; MnO_2 , &c.

M_2O =Suboxide, a very feeble base, the weakest. Ex. Ca_2O , &c.

The compounds of *O* and Manganese furnish a good illustration of the different oxides.

Protioxide of Mn = MnO , a powerful base. } Basic Oxides.
 Sesquioxide of Mn = Mn_2O_3 , a feeble base. }

Deutoxide of Mn = MnO_2 , neither basic nor acid. } Indifferent
 Oxide.

Manganic Acid= MnO_3 , a strong acid.

Permanganic Acid= Mn_2O_7 , a very strong } Acid Oxides.
 acid.

From this it may be inferred that in a family of oxides of an electro-positive body, the most powerful base is that containing one atom of *O*; and that as the quantity of *O* increases, the oxide passes from basic to indifferent, and, finally, from indifferent to acid.

113. Combustion may be defined to be "chemical combination attended by light and heat."

O has been termed a supporter of combustion, as distinguished from a combustible body, such as *P*. But we are not to suppose that the *O* has any greater or any different share in the combustion than the *P*. It so happens that the *O* is a gas while the *P* is a solid. Heat and light therefore appear to proceed from *P* alone, because the combustion or chemical combination can only take place where the two bodies are in contact. In reality, both bodies are equally concerned in the production of light and heat; and we may with equal accuracy consider *O* a combustible and *P* a supporter of combustion, as *P* a combustible and *O* a supporter of combustion.

In all combustion in our atmosphere, the heat and light, as above explained, appear to proceed from what is called the combustible or burning body because it is solid or liquid, or, if a gas, issues from a jet and is surrounded by an atmosphere containing O , which can only act on the combustible at the surface of the latter. But this is merely appearance; for while a jet of H burning in a jar of O appears to give out the light and the heat, a jet of O burning in a jar of H seems equally to be the source of heat and light, which, in both cases, proceed from the combination of the O and H .

If our atmosphere consisted of Coal Gas, we should have to search, not for coal to burn in it, but for substances capable of yielding O , such as Manganese, Chlorate of Potash, &c.

114. Many substances slowly unite with O , without the visible manifestation of light and heat, as when iron rusts, or wood decays in the air.

115. FIRST LAW OF COMBUSTION.—A given amount of a combustible body, when burned, will always furnish a constant amount of heat, whether the combustion occupies only a few moments or lasts during many years.

116. SECOND LAW OF COMBUSTION.—The amount of heat evolved bears a close relation to the amount of O consumed.

Thus a lb. of O combining with H , or with charcoal, or with alcohol, develops nearly the same amount of heat in each case, and will raise 20 lbs. of water from 32° F. to 212° F. The amount of heat evolved by equal weights of different combustibles combining with O , is as follows:

1 lb. of Carbon raises 78 lbs. of water from 32° to 212° F.
" Alcohol " 68 " " "
" Oil or Wax " 90 " " "
" Hydrogen " 236 " " "

Now 1 lb. of C combines with 2½ lbs. of O , and 1 lb. of H combines with 8 lbs. of O ; that is, H consumes three times as much O as C consumes, and consequently gives about three times as much heat.

117. The elements of most substances used for illuminating purposes are chiefly H and C . The affinity of O for H is superior to its affinity for C ; it therefore seizes upon the H first, burning it with intense heat, the solid C being at the same time set free. The particles of the C being thus heated to luminous whiteness, produce the light which is emitted from the flame. The luminous particles of C floating forward, as they are liberated, to

the surface of the flame, come in contact with the *O* of the atmosphere and pass off as Carbonic Acid, while the *H* is converted into water.

118. When the burning body contains both elements but a disproportionate amount of *C*, as in Spirits of Turpentine, more of it is set free than can be consumed by the *O*, and the flame smokes. When the *H* is in excess, as with Alcohol, there is much heat but little light and smoke. When mingled, these fluids correct each other's defects, and form the basis of "burning fluids."

119. Common flame is not, as it appears, a solid cone of fire, but a hollow luminous shell. This may be shown by holding a piece of metallic wire-gauze over the flame.

The dark central portion is constantly filled with gases formed from the tallow or oil by heat. A portion of these gases may be conveyed away by a glass tube and ignited at a distance from the flame.

120. In the common flame, several parts may be distinguished thus:

Fig. 2.

- I. A faint bluish exterior cone, *a*, where the combustion is complete.
- II. A bright luminous inner cone, *c*, consisting chiefly of particles of *C* intensely heated.
- III. An interior dark mass, *b*, consisting of unconsumed gases.



LECTURE VI.

HYDROGEN.

121. HYDROGEN. Symb. *H*; Equiv. 1; Comb. vol. 1; Spec. Grav. 0.0694; 100 cubic inches weigh 2.14 grs.

122. *H* is the lightest of all known substances, its weight being only one-sixteenth that of atmospheric air.

123. *H* when pure is without color, taste or smell (the *odor* pertaining to it, as commonly prepared, arises from impurities).

124. *H* is a combustible, but a non-supporter of combustion. If a lighted taper be introduced into a jar of *H*, the gas ignites directly the flame comes in contact with it, and the taper is extinguished by being immersed in the gas.

125. *H*, when perfectly pure, burns with an almost invisible flame.

126. Pure *H* may be breathed without injury, as it is not poisonous. It nevertheless produces a peculiar effect on the voice, imparting to it a shrill squeaking tone.

An animal placed in an atmosphere of *H* would soon die for the want of *O*.

127. A jet of *H* produces musical sounds when burned in glass tubes of different lengths. This *Music of Science* is produced by the successive explosions, which, in reality, constitute the flame, causing the air to vibrate within the tube.

128. *H* has never been reduced to the liquid, much less to the solid form, nevertheless many chemists suppose it to be a highly volatile metal. Its gaseous form is no objection to this theory, for mercury and certain other metals are very easily volatilized.

129. *H* may be prepared from *Zn* by the action of *HCl* or HO_3SO_3 . Iron filings may be substituted for *Zn*.*

* To prepare Hydrogen for experimental purposes, we obtain a wide-mouthed bottle, and pass two tubes through the cork, as in the accompanying figure—the upright tube reaching to within half an inch of the bottom of the bottle, and the other merely penetrating through the cork. In this bottle we place an ounce or two of zinc clippings or iron filings, and about one third fill the bottle with a mixture of 1 part sulphuric acid and 5 or 6 parts water. The gas that first escapes must not be collected, as, being mixed with the *O* of the air contained in the bottle, it would cause an explosion. The gas issues from the bent tube, and may be collected over the pneumatic trough in the same manner as *O*.

Fig. 3.



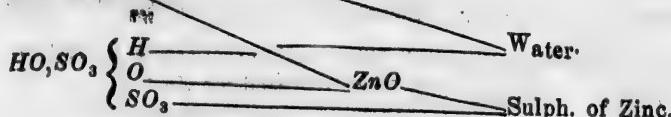
RE-ACTIONS.



130. When dilute Sulphuric Acid is used in place of Hydrochloric Acid the re-action may be represented as follows :



Or more probably as follows :—



131. H unites with O to form water—with Cl , Br , I and F it forms powerful acids the general formula of which is HM where M represents one atom of a metalloid—with C , S , P , Se , and As it forms combustible gases; with N it forms Ammonia; and probably two other compounds, Ammonium and Amidogen.

EXPERIMENTS.

I. Plunge a lighted taper into a jar of H (kept inverted in order to prevent the escape of the H), the taper is extinguished, but the H takes fire and burns slowly up the inside of the jar. Upon gradually withdrawing the taper, it rekindles as it passes through the burning H .

II. Mix in a softened bladder one volume of *O* with two volumes of *H*, and tie the neck of the bladder tightly. Then, having obtained a lighted taper attached to the end of a long stick, pierce the bladder with the blade of a penknife, and, standing as far off as possible, apply the flame to the orifice. The gases instantly combine with a loud explosion, and form water.

III. Fill an India-rubber gas-bag with *H*, and attach to the stop-cock a hydrogen pipe for blowing bubbles. Dip the pipe in a strong solution of soap, turn the stop-cock and press the gas-bag. A bubble is thus formed which detaches itself from the pipe, and rises through the air on account of the great levity of *H*. These bubbles may be exploded by a lighted taper.

132. If two volumes of *H* and one volume of *O* be mixed and fired, by electricity or otherwise, water is formed. Indeed water is formed whenever *H* burns in atmospheric air; and if it all be collected, it will be found to be just nine times the weight of the *H* consumed.

133. If, in a graduated tube, 210 volumes of *H* be mixed with 100 volumes of *O* and the mixture exploded, 10 volumes of *H* will remain unchanged. If the proportions had been 200 volumes of *H* and 110 volumes of *O*, 10 volumes of *O* would have been left. Hence 2 volumes of *H* unite with 1 volume of *O* to form water.

134. Water may be analyzed by Galvanic electricity. Thus: When the electric current of a powerful battery is made to pass through water in an apparatus so contrived that the gas given off at each electrode is received into a graduated tube, it is found that when the tube at the positive electrode is half full, the tube at a negative electrode is quite full; and, on examination, the gas in the latter is found to be pure *H*, while that in the former is pure *O*. The proportion by volume is evidently 2 of *H* to 1 of *O*, and by means of the specific gravities of gases we obtain the proportion by weight of 1 to 8.

WATER.

135. Water, symbol *HO*, equiv. 9, is, at ordinary temperatures, a colorless, tasteless and inodorous liquid; assumes the solid form at 32° F., and becomes gas, steam, or vapor at 212° F.

136. The point of greatest density of water is 39.2° F. The specific gravity of ice is 0.92. 1 cubic inch of water expands into 1 cubic foot of steam. 1 cubic foot of water weighs 1000 ounces avoirdupois; one gallon weighs 10 lbs.

137. Water is the most powerful solvent known. It is neither acid nor basic, but is perfectly neutral.

138. The compounds of water with acids and bases are called hydrates; as HO, SO_3 , hydrated SO_3 , HO, KO , hydrated KO , &c., to distinguish them from anhydrous SO_3 , anhydrous KO , &c.

139. The combination of water with other bodies is often attended with much heat. Ex. HO and SO_3 ; CaO and HO .

140. Water combines with neutral salts in two conditions. In the one it is easily expelled by heat, and the salt, if crystallized, falls to powder. This is called water of crystallization, and its quantity is often very great; as, for example, in Alum, which contains 24 equivalents. In the other, a portion of water, generally 1 equiv. is combined with the salt by so powerful an affinity as to be with some difficulty separated. This is called saline water. In formulæ, water of crystallization is sometimes represented by aq., and saline water by HO . Thus: green vitriol is represented as follows: $FeO, SO_3 + HO + 6\ aq.$ That is, 1 equiv. of sulphate of protoxide of iron, 1 equiv. of saline water, and 6 equiv. of water of crystallization.

When this salt is gently heated, the 6 equivalents of water of crystallization are expelled, but the 1 equivalent of saline water can only be expelled by a red heat.

141. The solvent power of water is generally increased by heat, so that a hot saturated solution of any salt usually deposits crystals on cooling. There are a few remarkable exceptions to this law. Thus: common salt is nearly equally soluble in water of all temperatures, and certain organic salts of lime dissolve more freely in cold than in hot water.

142. Water also dissolves, combines with or absorbs, as it is called, many gaseous bodies. The gas, in this case, is supposed

to assume the liquid state, and as heat tends to cause bodies to assume the gaseous form, it is obvious that heat must diminish and cold increase the solvent power of water for gases. Increased pressure also enables water to absorb more of a gas than it would do under ordinary circumstances—evidently because pressure favors the liquefaction of a gas by forcing the particles into closer contact.

143. A small portion of any one gas dissolved in water generally very greatly diminishes its power of dissolving other gases.

144. The proportion of different gases taken up by water is very variable. In its natural state it absorbs of

Hydrogen..... 1.6 per cent. of its volume.

Nitrogen..... 1.6 " "

Oxygen..... 4.0 " "

Olefiant Gas..... 12.5 " "

Carbonic Acid... 100.0 " "

Hydrochloric Acid Gas an amount = 480 times its volume.

Ammonia..... = 780 " "

145. In consequence of the great solvent power of water it is never found pure in nature. Even rain water, which is the purest, always contains traces of CO_2 , NH_3 , and sea-salt. When rain water has filtered through the soil, and reappears as spring or river water, it is always more or less charged with various salts derived from the earth, such as sea-salt, gypsum, and lime.

146. When the proportion of this dissolved salt is small, the water is called *soft*; when large, it is called *hard* water.

147. Hard water is usually preferred as a drink—the mineral salts dissolved in it and its free carbonic acid gas impart to it a slight but agreeable taste. It is not, however, as healthy a beverage as soft water, and is much inferior for all domestic purposes, as tea or coffee making, or where solution is to be effected, since it is already partly saturated, and dissolves additional substances but imperfectly.

148. When water becomes so highly charged with foreign matters as to have an unpleasant taste or to acquire medicinal virtues, it is called *mineral water*.

149. Of mineral waters there are several kinds, as *chalybeate* waters, containing Iron; *sulphurous* waters, containing Sulphur; *acidulous* waters, containing free Carbonic Acid gas; *alkaline* waters, containing the Carbonates of Potash and Soda; and *saline* waters, containing neutral salts generally, as Sea-salt and Sulphate of Magnesia (Epsom salts).

150. The only way to obtain perfectly pure water is by distillation.

151. Water plays a most important part in nature. It is one of the chief mechanical agents in the disintegration of rocks, as it enters the crevices, and there, freezing, bursts, by its expansion, the fragments asunder. Both gases and minerals enter the roots of plants dissolved in water. It forms the bulk of sap; it constitutes 80 per cent. of the blood and 74 per cent. of the flesh of animals, and is the natural beverage of all adult creatures.

DEUTOXIDE OF HYDROGEN OR OXYGENATED WATER.

152. Hydrogen forms a second compound with *O*, termed *Deutoxide of Hydrogen*, Symb. $HO_2 = 17$. It is a syrupy liquid, of a disagreeable odor, and a nauseous, bitter, astringent taste. It is not frozen by intense cold. It is easily decomposed, often with an explosion, and sometimes with a flash of light.

LECTURE VII.

NITROGEN.

153. NITROGEN. Symb. *N*; Equiv. 14; Comb. Vol. 1; Specific Gravity, 0.9722. 100 Cubic inches weigh 30.1 grs.

154. Nitrogen is obtained most readily by the action of burning phosphorus on a portion of air confined over water.

The phosphorus unites with the O , forming phosphoric acid, which is absorbed by the water, and nearly pure Nitrogen left.

155. N may also be obtained by causing a current of chlorine gas to pass through a solution of Ammonia in a proper apparatus, and with due caution.

156. Perfectly pure N may be obtained by heating a concentrated solution of Hyponitrite of Ammonia, the reaction being as follows :—



157. Nitrogen was discovered by Rutherford in 1772 ; and was called Azote or life-depriver. It was afterwards called Nitrogen, from its being one of the ingredients of Nitre or Saltpetre.

158. N is a colorless, transparent, permanently elastic gas; has neither taste nor smell; has no action on colored tests; is a perfect non-supporter of combustion, and is chiefly distinguished for its negative properties, i. e., it exhibits no tendency whatever to enter into combination with other substances.

159. Almost all the compounds of N are very easily decomposed, and many of them are even dangerous from their tendency to explode from very slight causes. The most important compounds of N are those with O and H .

160. Nitrogen forms an important constituent of atmospheric air, which is a mechanical mixture chiefly of nitrogen and oxygen.

Note.—The N in the atmosphere serves the purpose of *diluting* the O .

161. The composition of the Atmosphere is as follows;

	BY WEIGHT.	BY MEASURE.
Nitrogen,	77 parts	79·19 }
Oxygen,	23 "	20·81 } or $\frac{1}{2}$ N and $\frac{1}{2}$ O,
Carbonic Acid,	from 4 to 6 parts in 10,000.	
Light Carburetted Hydrogen "	" "	
Aqueous vapor, variable.		
Ammonia, a trace.		

162. The amount of *O* in atmospheric air may be measured in several ways.

- I. By passing air through a tube containing pure metallic spongy copper heated to redness. The copper combines with the *O*, and the *N* is collected and weighed. The loss of weight gives the amount of *O*.
- II. By placing a stick of phosphorus in a graduated tube containing a known quantity of air standing over water. The *O* is slowly absorbed, and the loss of volume gives the amount of *O*.
- III. By explosion with the Eudiometer. A known volume of *H* is introduced into a known volume of atmospheric air, and exploded; one-third the loss in volume being the *O*.

Figure 4 represents the Siphon Eudiometer of Dr. Ure. This consists of a bent glass tube having a bore of about one-third of an inch in diameter. The tube is open at one end and closed at the other, and near the top of the closed limb two platinum wires are melted through the glass, so as nearly to touch one another within the tube. Finally the closed limb of the Eudiometer is carefully graduated. When required for use, the instrument is filled with mercury, and the portion of air to be examined is then introduced into the closed limb. The mercury is now adjusted so as to have the same level in each limb, and the quantity of air introduced measured by the graduated scale. As nearly as possible half as much Hydrogen is then introduced, and the level

Fig 4.



of the mercury again adjusted. One of the platinum wires is now connected with the outside of a charged Leyden jar, and, having first closed the open end of the Eudiometer with the thumb or with a tight cork, an electric spark is passed through the confined gas and air. The H instantly unites with the O , and the mercury rises in the closed limb.

Thus: suppose Air introduced = 100 measures.
 Hydrogen = 50 "

Air and Hydrogen = 150 "
 Volume after explosion = 87 "

Loss of Volume = 63 "

Then $63 \div 8 = 21$ = measures of O in 100 measures of Air.

163. 100 cubic inches of atmospheric air, under the usual conditions, weigh about 31 grains.

164. The O of the air is constantly consumed by animals. The exhalations from the skin and lungs of a single human being vitiate or spoil for breathing 10 cubic feet per minute, or 90,000 gallons of air per day. Also combustion removes O , and in both cases the result is Carbonic Acid Gas which is poisonous to animals. On the other hand, plants constantly absorb Carbonic Acid, and exhale O . Thus plants and animals mutually prepare the air for supporting each other's life.

165. The atmosphere is partly kept pure by the remarkable law of *gaseous diffusion*. Thus if two bottles connected by a tube and stop-cock be placed one over the other, and if the upper be filled with any light gas, and the lower with a heavy gas, and if the stop-cock be turned so as to allow a communication to exist between the two bottles, in a short time the gases will be found to be intermixed. That is, in opposition to the law of gravity, the light gas descends and the heavy one rises, and the two intermingle.

COMPOUNDS OF NITROGEN WITH OXYGEN.

166. NITROUS OXIDE; PROTOXIDE OF NITROGEN; LAUGHING GAS. Symb. $NO = 22$. Is a colorless, transparent gas; has a faint smell and a sweetish taste; is slowly absorbed by water; spec. grav. 1.527; is prepared by applying a moderate heat to pure

Nitrate of Ammonia, and may be collected over tepid or warm water; liquefies at 0° under a pressure of 30 atmospheres; supports flame; is not poisonous, but produces a remarkable effect when inhaled.

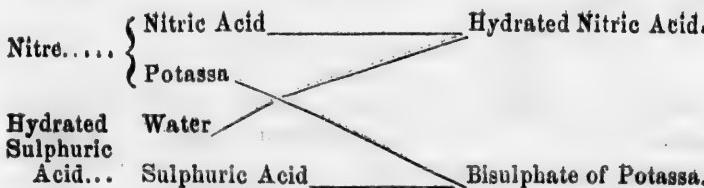
167. NITRIC OXIDE; DEUTOXIDE OF *N*; NITROUS GAS. Symb. $NO_2 = 30$. Is a colorless, transparent gas; seizes *O* when in contact with air, and forms red fumes of nitrous acid gas; best obtained by treating copper clippings with dilute nitric acid; is collected over water; extinguishes some flames, but supports others. Spec. grav. 1.041,—has no action on colored tests.

168. HYPERNITROUS ACID. Symb. $NO_3 = 38$; is obtained with difficulty; is a very volatile liquid, which is colorless while cold, but at ordinary temperatures becomes green; combines with bases to form hypernitrites; reddens vegetable blues.

169. NITROUS ACID; HYPERNITRIC ACID. Symb. $NO_4 = 46$. Is obtained by mixing one vol. of *O* with 2 vols. of dry Nitric Oxide in an exhausted receiver; is a deep red vapor, condensable to an orange liquid at 0° , and solidifiable at a lower temperature. The liquid boils at 82° , and has a spec. grav. of 1.45, that of the vapor being 3.19. NO_4 is an acid, but does not form salts with bases, being decomposed, and hypernitrites and nitrates formed; reddens blue tests.

170. NITRIC ACID. Symb. $NO_5 = 54$. This most important of all compounds of *N* and *O* has recently been obtained perfectly anhydrous. The hydrate is best obtained by distilling a mixture of equal weights of hydrated sulphuric acid and of nitre or saltpetre (i. e. nitrate of potash.)

RE-ACTION.



171. Nitric Acid is a colorless, intensely acid liquid; spec. grav. 1·45; a powerful deoxidizer; combines with bases to form nitrates, reddens blue strongly, exists in nature as Nitrate of Potash, &c., formed in the air by electric sparks and flashes of lightning; is used in the arts to oxidize and dissolve metals; is of great importance in dyeing, metallurgy, and medicine.

COMPOUNDS OF NITROGEN WITH HYDROGEN.

172. Nitrogen is supposed to form three compounds with *H*, viz.: Amide or Amidogen, Ammonia, and Ammonium, of which Ammonia alone is known in the separate state.

173. AMMONIA; VOLATILE ALKALI; SPIRITS OF HARTSHORN. Symb. $\text{NH}_3 = 17$, occurs in nature in the urine of animals as urate of ammonia; in combination with *HCl* as sal-ammoniac; and in the air as a constant result of the putrefaction, decay and combustion of organic matters containing *N*. Ammonia was formerly obtained from the destructive distillation of horn, and was hence called hartshorn. It is a transparent and colorless gas, which is converted into a liquid by a pressure of about 6 $\frac{1}{2}$ atmospheres, and is similarly condensed by a temperature of 40° F.; by a very intense cold it is frozen to a white crystalline mass; it has a powerful and peculiar pungent smell and taste; is strongly alkaline, and is hence called the volatile alkali; acts powerfully on colored tests; is obtained by heating sal-ammoniac with quick lime; is slightly combustible, but is a non-supporter of flame; its spec. grav. is 0·5902; readily combines with acids to form salts; water absorbs 780 times its volume of ammonia, and forms aqua ammoniae.

174. AMIDE OR AMIDOGEND. Symb. $\text{NH}_2 = 16$. A hypothetical compound; has never been obtained separately, but is supposed to exist in combination with metals, as Amides, and in organic compounds.

175. AMMONIUM. Symb. $\text{NH}_4 = 18$. Is also a hypothetical compound, i. e., does not exist in a separate state, but is supposed to exist in an independent state in some of the compounds of Ammonia, as a metal NH_4 , or as an oxide $\text{NH}_4\text{O}^{\circ}$.

LECTURE VIII.

CARBON.

176. CARBON.—Symb. *C*; Equiv. = 6; Comb. vol. of (hypothetical) vapor = 1. Name from *carbo*, a coal. Exists in three allotropic states.

177. I. Diamond—found in India, Borneo, Brazil, &c.; crystallized in regular octahedrons; is sometimes colored, but the transparent is considered the most valuable; is the hardest substance known; infusible, but is combustible at a white heat; can only be polished or cut with its own dust; is used as a gem, also for cutting glass and for pivot rests in delicate machinery, as watches, &c. Diamonds are sold by the carat (3.2 grains), and they increase in value in proportion to the square of their weight. The average value of a wrought diamond of one carat is \$40, therefore value of one of 2 carats = $40 \times 4 = \$160$, one of 10 carats = $40 \times 100 = \$4000$, of 100 carats = \$400,000, &c. The largest known diamond is probably the “Kooh-i-Noor” (mountain of light), which was discovered in the mines of Golconda three hundred years ago, and is said when rough to have weighed 900 carats. It has been reduced by cutting to 279 carats, and although never sold is said to be worth \$10,000,000. It has caused several wars, and has been six times violently wrested from its possessors. It now belongs to the crown of England. If a piece of diamond and a piece of pure soft iron be sealed together and exposed to an intense heat, the iron is converted into steel, thus proving the diamond to be carbon. Diamond is, in fact, the purest kind of *C*.

178. II. Graphite—Plumbago—Blacklead—is the second allotropic form of *C*. This rarely occurs in crystals which are six-sided prisms. It is sometimes rendered impure by containing iron which varies in quantity from a trace up to 5 per cent. It resists a very intense heat, and is therefore used for making crucibles, also used to diminish friction, and in the manufacture of black lead pencils.

179. III. Lampblack and charcoal are examples of the third allotropic form of *C*. In this state it is amorphous.

180. *C*, as diamond, is a non-conductor of electricity, while as graphite or charcoal it forms an excellent conductor.

181. Charcoal—is obtained from burning organic matter (wood, bones, etc.,) out of contact with air; appears to be soft, but the fine particles are exceedingly hard, and easily scratch glass; is used for fuel; when pure, burns without flame; is very indestructible,—charred stakes remain centuries buried in the earth without decomposing; the most important property of charcoal is its absorbent power; absorbs 90 times its bulk of Ammonia, 35 times its bulk of Carbonic Acid Gas, 9 of *O*, and 7 of *N*; also absorbs a large quantity of water; a cubic inch of charcoal is supposed to possess 100 square feet of surface; from its absorbent capabilities arise its antiputrescent and disinfecting powers; newly prepared charcoal at once sweetens tainted meat or fish; the inside of casks is charred in order to preserve water; charcoal is used as a filter; from its absorbent power also arises the great value of its action upon soils.

182. Carbon exists native in the Diamond, Graphite, &c.—and is also found in combination with many of the other elements, as Carbonate of Lime, Marble, Chalk, or Limestone; Carbonate of Magnesia, Carbonate of Baryta, Carbonate of Strontia, Carbonate of Lead, &c. It is an essential ingredient of all organized tissues and products, animal and vegetable.

183. Animal matters when burned yield animal charcoal, which contains phosphates. Charcoal from bones is termed bone-black or ivory-black, and is of course loaded with phosphate of lime; it is, however, the best of all decolorizers. Oils and resins burned with deficiency of *O*, yield lampblack, which is nearly pure *C*.

COMPOUNDS OF CARBON AND OXYGEN.

184. Carbon unites with *O* to form several compounds, the most important of which are Carbonic Oxide, Oxalic Acid, and Carbonic Acid.

185. CARBONIC OXIDE, Symb. $CO=14$, Spec. Gravity 0·972, is obtained by heating in a retort 1 part of finely powdered Ferrocyanide of Potassium with ten parts of Oil of Vitriol ; may be collected over water ; is transparent and colorless ; has neither taste nor smell ; is poisonous when respired ; extinguishes flame, but burns itself with a clear lambent blue flame, generating Carbonic Acid ; is a compound radical.

186. CARBONIC ACID ; FIXED AIR ; MEPHITIC GAS ; CHOKE DAMP. Symb. $CO_2=22$; Spec. Grav. 1·527.—Exists in the atmosphere ; is formed by combustion, respiration, fermentation, decay, and volcanic action ; exists also in Carbonates of Lime, Magnesia, Iron, Copper, &c.

187. Carbonic Acid may be formed by burning any of the forms of carbon in air or in O_2 , or by decomposing a carbonate by a more powerful acid ; it may be collected over water with considerable loss, or by simple displacement.

188. CO_2 is a transparent, colorless gas ; soluble in water ; poisonous if respired ; a non-supporter of combustion ; liquefies under pressure of 40 atmospheres, and when the pressure is suddenly removed, a portion abstracts heat and becomes gas, the remainder becoming a solid, like snow, which, when dissolved in ether and allowed to evaporate, produces the most intense cold known (-200° F.) ; a bottle of mercury of several pounds may be frozen in a few minutes if placed in contact with this mixture. The acid powers of CO_2 are so very feeble, that it scarcely reddens blue tests ; combined with bases, it forms carbonates, and it is expelled with effervescence from these compounds by every other acid, except hydrocyanic. It is essential to the growth of plants, and is employed in the manufacture of the various carbonates and of effervescent mineral water ; causes stupor and finally death if mixed with air even in the proportion of 1 to 10 ; is exhaled from fissures in the earth in volcanic countries, as, for example, in the Grotto del Cano, the Valley of Death, &c.

189. OXALIC ACID, Symb. C_2O_4+3HO , is obtained by acting on sugar by nitric acid and purifying by crystallization ; exists

native in rhubarb, sorrel, and many other plants; has not been obtained independent of water or a base; the hydrate is a white crystalline solid, subliming at about 300° F.; soluble in water; strongly acid; reddens vegetable blues; combines with bases to form oxalates; is very poisonous (antidote chalk or magnesia).

190. The other compounds of *C* and *O* are Croconic Acid, C_4O_4+HO ; Rhodozonic Acid, C_7O_7+3HO , and Mellitic Acid, C_4O_3+HO .

COMPOUNDS OF CARBON AND HYDROGEN.

191. The compounds of *C* with *H* are very numerous, and belong chiefly to organic chemistry. The most important hydrocarbons are Light Carburetted Hydrogen, Olefiant Gas, Gutta Percha, Caoutchouc, Naphtha, Camphene; and the hypothetical hydrocarbons, Methyle, Ethyle, Amyle, Acetyle, &c.

192. Light CARBURETTED HYDROGEN, MARSH GAS, FIRE DAMP, Symb. $CH_2 = 8$, Spec. Grav. 0.555; 100 cubic inches weigh 17.4 grains; produces the bubbles arising from pools of stagnant water; is obtained in the laboratory by heating a mixture of 40 parts crystallized Acetate Soda, 40 parts solid Hydrate of Potassa and 60 parts of quick-lime in powder; it may be collected over water; is a colorless, transparent gas; extinguishes flame, but burns itself with a light yellow flame; when pure is nearly destitute of smell; is not acted upon by Chlorine in the dark; forms an explosive mixture with common air, 2 volumes of *O*, or 8 volumes of air to 1 of gas, most explosive; this is the fire damp of mines; miners not killed by the explosion are mostly suffocated by the choke damp or after damp (CO_2) formed by the explosion, thus— $CH_2+O_2=CO_2+2HO$.

NOTE.— CH_2 is not explosive when mixed with less than 5 vols. or with more than 15 vols. of air. It requires a bright white heat, as flame, to ignite the explosive mixture. Davy's Safety Lamp depends upon the fact that metallic wire gauze, having not less than 400 meshes to the square inch, is not permeable by flame.

193. OLEFIANT GAS, HEAVY CARBURETTED HYDROGEN; BICARBIDE OF *H*; $C_2H_2 = 14$; Spec. Grav. 0.98; 100 cubic inches weigh 31.7 grains; may be obtained by heating 1 part by weight of Alcohol with 5 or 6 of HO, SO_3 ; may be collected over water; is a colorless gas, which by cold and pressure may be liquefied;

when pure has neither taste nor smell; extinguishes flame, but burns itself with a splendid light; is the most important constituent of coal or illuminating gas. 1 vol. of C_2H_2 , mixed with 3 vols. of O or 15 vols. of air, explodes with extreme violence; mixed with its own vol. of Chlorine, the two gases rapidly disappear and produce an oily liquid, hence the name *olefiant*; when mixed with twice its vol. of Chlorine the mixture burns off with a red flame, and an immense quantity of smoke, which is carbon, is deposited in the solid form.

194. COAL GAS is obtained from the destructive distillation of bituminous coal in iron cylinders kept at a bright red heat; the volatilized products are conducted through a horizontal pipe of large dimensions (called the hydraulic main); they next traverse the refrigerator or cooler where tar and ammoniacal liquor condense; the residue is purified from CO_2 and Sulphuretted H in lime purifiers, and from ammonia by passage through dilute Sulphuric Acid.

195. Methyle = C_2H_3 ; Ethyle = C_4H_6 ; Amyle = $C_{10}H_{11}$; Acetyle = C_4H_3 ; are *hypothetical* compound radicals.

196. Naphtha C_6H_5 —Mineral Naphtha exists native in Italy, Russia, &c. Coal Naphtha is obtained during the destructive distillation of coal; both kinds are colorless liquids, having a spec. grav. of about 0.800; are very inflammable; dissolve most resins and oils; are used as solvents for caoutchouc. Mineral Naphtha is also used to preserve Potassium, Sodium, and similar oxidizable substances.

COMPOUNDS OF CARBON AND NITROGEN.

197. CYANOGEN, C_2N or *Cy*, is obtained by heating 6 parts of dried Ferrocyanide of Potassium with 9 parts of Bichloride of Mercury. It may be collected over mercury. Spec. Grav. 1.82; is a transparent colorless gas, which is rapidly absorbed by water. It may be condensed into the liquid state by a pressure of 4 atmospheres, and is then solidifiable by a cold of 30° ; has a penetrating peculiar odor like oil of bitter almonds; is highly poisonous; extinguishes flame, but burns itself with a beautiful

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purple red flame; though a compound, it has a remarkable analogy to Chlorine, and to certain other compounds, such as Ammonium.

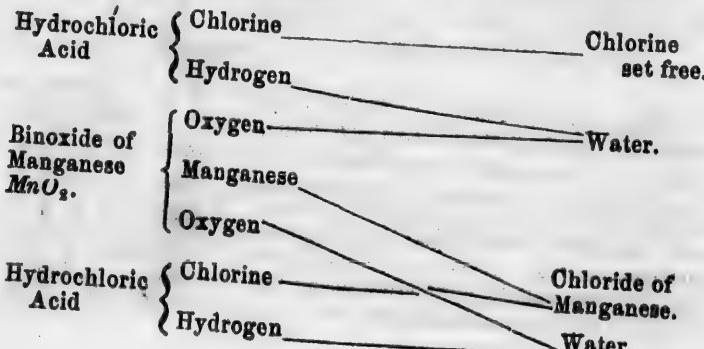
198. Cyanogen with O forms Cyanic Acid, CyO ; Paracyanide, Cy_2O_2 (fulminic acid), and Cyanuric Acid, Cy_3O_3 .

199. Cyanogen with H forms Hydrocyanic Acid or Prussic Acid, HCy , which exists naturally in some plants, and is obtained artificially by distilling Cyanide of Mercury with Hydrochloric Acid or by decomposing it by Sulphuretted H, and condensing the vapor by a cold of 0° . It is a transparent colorless liquid, very volatile, and solidifying by the cold of its own evaporation. It is highly poisonous; spec. grav. 0·700; is combustible, burning with a bright flame; is very prone to decomposition, which is prevented by the presence of a trace of any other acid. Its acid powers are so feeble that it does not expel Carbonic Acid from carbonates. A dilute solution (97 parts pure water + 3 parts HCy) is cautiously employed in medicine.

LECTURE IX.

CHLORINE.

200. Chlorine; Symb. Cl; Equiv. 35·5; Comb. Vol. 1; Spec. Grav. 2·47; 100 cub. in. weigh 78 grains; was discovered by Scheele in 1774; name derived from *chloros*, "yellowish green;" may be prepared by heating Binoxide of Manganese with Hydrochloric Acid, as follows:—

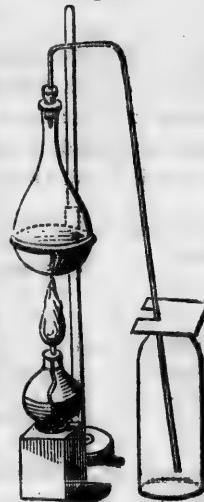


201. Chlorine may be collected by displacement or over tepid water;* it is a transparent, greenish yellow suffocating poisonous gas, soluble in cold water, condensable under pressure of $4\frac{1}{2}$ atmospheres to an oily fluid whose spec. grav. is 1.33. *Cl* has a strong affinity for metals, with which it forms Chlorides; when dry it has little action on vegetable colors, but when moisture is present it bleaches them; is a strong disinfectant; its bleaching and disinfecting powers are due to its strong affinity for *H* which it takes away from coloring and putrescent substances, thus decomposing them; is very irritating to the lungs when breathed, yet it is said to alleviate symptoms of consumption when respired in very minute quantities. Workmen employed in bleaching establishments and other places where Chlorine is used, are said to suffer but little from consumption. *Cl* is said to quicken the germination of seeds. Water absorbs twice its volume of this gas, assumes a green color, and is then called Chlorine water.

EXPERIMENTS.

- I. Dip a roll of paper in turpentine, and then place it in a jar of Chlorine.
- II. Drop some pulverized metallic Antimony into a bottle of *Cl*.
- III. Put a small piece of gold leaf into some Chlorine water.
- IV. Mix a few drops of Chlorine water with some ink.
- V. Introduce a piece of printed calico into some Chlorine water.

Fig. 5.



* In order to prepare Chlorine we obtain a moderately large glass flask which we fill to the extent of not more than one-third, with a mixture of 1 measure finely powdered Black Oxide of Manganese and 11 or 12 measures of liquid Hydrochloric Acid. Beneath the flask we place the flame of a spirit-lamp, and collect the gas by simple displacement, as exhibited in the arrangement represented in the accompanying figure.

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- VI. Strongly perfume a handkerchief, and drop some Chlorine water upon it.
 VII. Drop a piece of metallic Sodium into some Cl .
 VIII. Introduce a piece of dry Phosphorus into a jar of Cl .
 IX. Mix 2 vols. of Cl with 1 of Olefiant Gas, and fire the mixture.
 X. Mix 1 vol. of Cl with 1 of Olefiant Gas over water.

COMPOUNDS OF CHLORINE AND OXYGEN.

202. HYPOCHLOROUS ACID, ClO , is an orange yellow liquid which boils at 68° , and is obtained by action of Chlorine on Red Oxide of Mercury, the reaction being as follows:



The vapor of Hypochlorous Acid is deep yellow, spec. grav. 2.977, is readily absorbed by water to the extent of 200 volumes; explodes by heat or by mere contact with many combustible substances, so that experiments with it require the greatest caution; its solution bleaches powerfully.

203. CHLOROUS ACID, ClO_2 , is a greenish yellow gas, not liquefied by a cold of $5^{\circ} F.$, decomposed by light, also by heat of 140° , may be made by cautiously acting on small quantities of Chlorate of Potash by Sulphuric Acid with very gentle heat. Spec. grav. 2.33; explodes furiously from slight causes, the heat of the hand often being sufficient to cause its decomposition. Its smell is peculiar, almost aromatic.

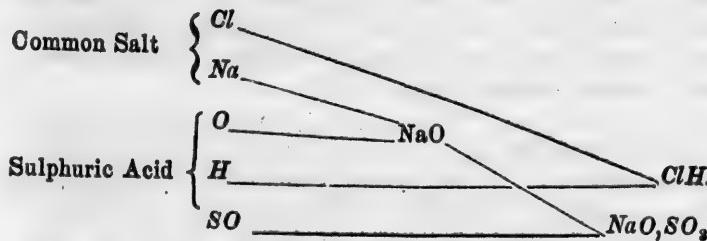
EXPERIMENT.—Place a little Chlorate of Potash and a few crumbs of Phosphorus in a small jar of water, and by means of a dropping tube treat it with Sulphuric Acid, the P burns in the Chlorous Acid set free.

204. CHLORIC ACID, ClO_5 , is formed when Cl is passed through a hot and strong solution of any alkali, as potash; or when Chlorate of Baryta is dissolved in water, and Sulphuric Acid added so as to exactly precipitate all the baryta as sulphate. ClO_5 does not exist independent of a base except in solution which is a thick syrup-like sour liquid, decomposed by a heat of 100° F.; forms salts termed chlorates, which are quite permanent, but which explode by friction or percussion when in contact with a combustible, as sulphur, phosphorus, or charcoal.

205. PERCHLORIC ACID, ClO_7 , is formed by the action of oil of vitriol on hyperchlorate of potash. It has not been obtained quite anhydrous; its hydrate is a white volatile crystalline solid, very deliquescent and very soluble in water forming a colorless fuming sour liquid, which has a spec. grav. of 1.65, and which boils at about 400° .

COMPOUNDS OF CHLORINE AND HYDROGEN.

206. HYDROCHLORIC ACID, Symb. HCl , is a transparent colorless gas; spec. grav. 1.262; fumes in the air, absorbing moisture. HCl is obtained by the action of Sulphuric Acid on common salt.



207. Hydrochloric Acid extinguishes flame, is a powerful acid, reddens litmus and also turmeric paper, may be liquefied by a pressure of 40 atmospheres; is very soluble in water, the solution forming the common or liquid Hydrochloric Acid of the shops.

208. Two measures of HCl mixed with one measure of NO_5 form the Aqua Regia or Nitro-muriatic Acid of chemists.

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209. Chlorine unites with *N* to form Perchloride of *N* or Oil of Azote NCl_4 , which is obtained by acting on a solution of sal-ammoniac by *Cl*. Perchloride of *N* is a yellow oily fluid, insoluble in water, and most violently explosive and dangerous.

LECTURE X.

IODINE, BROMINE, FLUORINE.

210. IODINE, Symb. *I*; Equiv. 127; Comb. Vol. (vapor) 1; Spec. Grav. 4.948: Spec. Grav. of vapor 8.716. Iodine was discovered by Courtois of Paris in the year 1812; was named from ion "a violet" in allusion to its purple fumes; native sources are sea water, rough sea salt, various marine plants and animals, some mineral springs and certain rare lead and silver ores. *I* is obtained by heating the uncry stallizable residue of kelp (half vitrified ashes of sea weeds, prepared by the people of the Western Isles) with Oxide of *Mn* and Sulphuric Acid.

211. Iodine is a bluish black semi-metallic looking, friable crystalline solid, easily volatile, fuses at 225° , and boils at 350° , forming violet colored vapor; is soluble in 7000 times its vol. of water, much more soluble in Alcohol or in solutions of the iodides of the alkaline metals; is used in the arts for dyeing, and also in medicine. Iodine communicates to the skin a fugitive yellow stain, and exhales a strong odor like that of the sea beach. Phosphorus takes fire spontaneously in *I*. Iodine gives a blue color to a solution of starch, and, in fact, starch and *I* are mutual tests. *I* enters into combination with metals, and forms iodides.

212. *I* unites with *H* to form Hydriodic Acid, $\text{HI} = 128$, which is obtained by gently heating a mixture of 1 part phosphorus and 16 Iodine stratified, in a small flask, with moistened sand. *HI* is a transparent colorless acid gas, very suffocating to the smell, and greatly resembling *HCl*. It has a spec. grav. of 4.385; is soluble in water; condensable by pressure, and solidifiable by cold.

213. *I* unites with *O* to form Iodic Acid and Periodic Acid.

214. IODIC ACID, IO_5 , is a white solid, obtained by the action of strong NO_3 on *I*. It is soluble in ether, alcohol and water, forming a strong sour solution, which is decomposed by heat. IO_5 forms iodates which much resemble the chlorates.

215. PERIODIC ACID, IO_7 , is a white solid hydrate, and is obtained by decomposing periodate of silver by water. It forms white crystals which fuse at 266° and are decomposed by a higher temperature; IO_7 readily dissolves in water.

216. *I* unites with *N* to form Iodide of $N = NI_3$; which is a black solid substance extremely explosive.

217. *I* also forms two compounds with Chlorine and one with Bromine.

BROMINE.

218. BROMINE, Symb. *Br*; Equiv. 80; Comb. Vol. (vapor) 1; Spec. Grav. 2.966, of vap. 5.39. *Br* was discovered by M. Balard of Montpelier in the year 1826, and was named from *Bromos* "fetor." It is found in sea water, mineral springs, mother liquor of kelp, native bromide of silver, &c.; is obtained by action of Chlorine on bittern and subsequent agitation with ether, which dissolves the *Br* and carries it to the surface.

219. Bromine is a deep red volatile liquid, solidifies at 40° , boils at 113° , giving off a red vapor. It is slightly soluble in water, more freely in alcohol, and most abundantly in ether; the aqueous solution bleaches; *Br* bears a marked resemblance to *Cl* and *I*; it supports the combustion of *P* and many metals, and forms *bromides* which are analogous to the *chlorides*.

220. *Br* unites with *H* to form HYDROBROMIC ACID, HBr , which is scarcely distinguishable from HCl , and is obtained in a similar manner to Hydriodic Acid.

221. *Br* unites with *O* to form BROMIC ACID, BrO_5 , which exists only as an aqueous solution, and is obtained in the same manner as Chloric Acid.

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FLUORINE.

222. FLUORINE, Symb. *F*; Equiv. 19; was discovered by Davy, and named from its existence in Fluor-spar; it has not been isolated, i. e., is known only in combinations; it bears a close analogy to *Cl*, *I* and *Br*.

223. *F* unites with *H* to form HYDROFLUORIC ACID, *HF*, which is obtained by action of Oil of Vitriol on Fluor-spar (Fluoride of Calcium); is a very volatile liquid, strongly acid and corrosive; burns the skin like red hot iron, and produces a sore very difficult to heal; both the acid and its vapor rapidly decompose glass and corrode it, uniting with the silica, and are hence used for etching on glass.

LECTURE XI.

SULPHUR.

224. SULPHUR, Symb. *S*; Equiv. 16; Comb. Vol. (vapor) $\frac{1}{6}$; Spec. Grav. 2.000; called also Brimstone (i. e. burnstone or burning stone); exists nearly pure in volcanic regions as Sicily, India, South America, &c.; is also found in combination with metals, as *sulphides*; also as Sulphuric Acid in the *sulphates*, as gypsum; also in organic matter.

225. Sulphur is obtained from the sulphides by heat, which vaporizes the *S*; is obtained pure from common brimstone by sublimation; is a pale, yellow, brittle, tasteless, inodorous solid, fuses at 226° and boils at 600° giving off a deep brownish yellow vapor or gas,—up to 390° it is liquid, at that point it becomes thick and viscid, is fluid again at or near the boiling point, and on cooling goes through the same series of changes. If kept heated to between 500° and 600° for some time and then poured in a thin stream into cold water it becomes a flexible viscid mass easily pressed into any shape, and much used for taking casts of medals, &c.; this form passes gradually into the brittle variety.

226. Sulphur unites with the metals to form sulphides ; it unites with them in a manner similar to *O* and *Cl*; *S* is insoluble in water, but is soluble in alcohol, ether and oils ; also in Bisulphide of Carbon and Chloride of Sulphur ; is very combustible, and burns at a very low temperature.

227. Brimstone is usually sold in rolls which are cast in a mould ; *flowers of sulphur* is obtained by vaporizing sulphur and condensing it in chambers ; a third variety, *lac-sulphuris*, which is a precipitate of a white color, is prepared by treating Persulphide of Potassium with Hydrochloric Acid.

COMPOUNDS OF SULPHUR AND OXYGEN.

228. Sulphur forms several compounds with *O*, the most important being Sulphurous Acid and Sulphuric Acid.

229. **SULPHUROUS ACID**, SO_2 ; spec.grav.2.210; is formed when *S* is burned in the air or in *O* or by treating Sulphuric Acid with Mercury ; is a transparent gas, condensable by a pressure of two atmospheres and solidifiable by cold ; extinguishes flame, is irrespirable, and has a suffocating odor. Water absorbs about 50 times its own vol. of SO_2 forming liquid Sulphurous Acid or more properly a solution of Sulphurous Acid ; this, if exposed to the air, absorbs *O* and is converted into Sulphuric Acid. SO_2 combines with bases to form sulphites. SO_2 possesses considerable bleaching properties, and is used in the arts as a means of removing colors.

230. **SULPHURIC ACID**, SO_3 , is the most important of all acids, and has been known since the 15th century ; is prepared in two modes. First, when green vitriol (green Sulphate of Iron) is distilled, a dark oily liquid, hence termed oil of vitriol, passes over ; this is, in reality, German or Nordhausen oil of vitriol, = $HO, SO_3 + SO_3$ —a very strong corrosive oily liquid, having a spec. grav. of 1.900.

231. The second method of manufacturing Sulphuric Acid depends upon the fact that when Sulphurous Acid, Hyponitric Acid and water are all present in certain proportions, the Sulphurous Acid becomes oxidized at the expense of the Hyponitric Acid,

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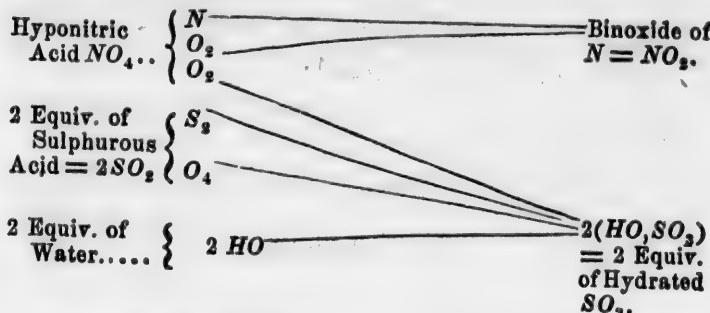
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which, by the loss of one-half its O , sinks to the condition of Binoxide of Nitrogen. Thus :



232.—HYDRATED SULPHURIC ACID, or common oil of vitriol, is a colorless oily liquid; spec. grav. 1.84, solidifying at 15° and boiling at 620° ; is an intensely acid, powerful acid, which destroys organic matter rapidly; combines with bases to form sulphates; displaces almost all other acids in consequence of the strong affinity which it has for bases; is used in the arts in the manufacture of soda, nitric acid, muriatic acid, chlorine, bleaching power, sulphates, alum, &c.; also in metallurgy.

233. SULPHURIC ACID combines with water in several proportions. Among the different hydrates, the following are the most important :—

Hydrate of the Nordhausen Acid,.....	$HO, 2SO_3$
Oil of Vitriol (spec. grav. 1.84),.....	HO, SO_3
Acid of " " 1.78,.....	$HO, SO_3 + HO$
Acid of " " 1.63,.....	$HO, SO_3 + 2HO$

234. ANHYDROUS SULPHURIC ACID, SO_3 , has recently been obtained in the form of a white silky looking fibrous solid, having a powerful affinity for water, fusible at about 75° , readily volatile, and having a density of about 1.97.

235. Chemists are very generally agreed that all the so called Oxygen acids are in reality Hydrogen acids. No well marked acid exists in which H is not present, and all the sulphur acids possess the same neutralizing power though the quantity of O

they contain is so different. H is therefore to be considered as the "acidifying principle," and an acid may be defined to be "*a compound of hydrogen with a simple or compound radical in which the H may be replaced by any other metal.*"

236. The following are the compounds of S and O according to the old and new systems.

Acids.	Old View.	New View.	Equivalents where H unites with the compound radicals SO_3, SO_3+O , &c.
Sulphurous Acid,.....	HO, SO_2	H, SO_3	$H+SO_3$.
Sulphuric Acid,.....	HO, SO_3	H, SO_4	$H+(SO_3+O)$.
Hyposulphurous Acid,..	$HO, S_2 O_2$	$H, S_2 O_3$	$H+(SO_3+S)$
Hyposulphuric Acid,..	$HO, S_2 O_5$	$H, S_2 O_6$	$H+(SO_3+SO_3)$.
Trithionic Acid,.....	$HO, S_3 O_5$	$H, S_3 O_6$	$H+(SO_3+SO_3+S)$.
Tetrathionic Acid,....	$HO, S_4 O_5$	$H, S_4 O_6$	$H+(SO_3+SO_3+S_2)$
Pentathionic Acid, ...	$HO, S_5 O_5$	$H, S_5 O_6$	$H+(SO_3+SO_3+S_3)$

COMPOUNDS OF SULPHUR AND HYDROGEN.

237. SULPHURETTED HYDROGEN, Symb. HS , is spontaneously generated by the decomposition of organic substances containing sulphur; is prepared by acting on the Protosulphide of Iron by Hydrochloric or dilute Sulphuric Acid; is a colorless transparent gas, having a very offensive and peculiar smell like that of putrid eggs; is condensable under a pressure of 17 atmospheres, and is solidifiable by cold; it may be collected over water, which however gradually absorbs it. HS is highly poisonous, and often causes death; small birds die very soon in gas containing $\frac{1}{100}$ of this gas; $\frac{1}{800}$ killed a dog; and $\frac{1}{170}$ a horse. It has a spec. grav. of 1.1786; it extinguishes flame, but burns itself with a pale flame forming water and SO_2 . Water absorbs two or three times its vol. of HS .

238. Persulphide of H has a composition of HS_2 , but is not at all important.

239. Sulphur forms two compounds with Chlorine, viz.: Subchloride of $S = S_2Cl$, and Chloride of $S = SCl$, and it also forms analogous compounds with I and Br .

240. With Carbon, Sulphur forms Bisulphide of Carbon, CS_2 , which is obtained by passing the vapor of sulphur over ignited charcoal, and condensing the result by cold. CS_2 is a transparent colorless liquid, insoluble in water, possesses a strong and disagreeable fetid odor; spec. grav. 1.272; boils at 118° ; is very volatile; dissolves Sulphur, Phosphorus, most oils, resins, &c., exists often in coal gas, from which it cannot be separated by lime like the other sulphur compounds.

241. Sulphur and N form Tersulphide of Nitrogen = NS_3 .

LECTURE XII.

PHOSPHORUS.

242. PHOSPHORUS, Symb. P ; Equiv. 32; Spec. Grav. 1.77, was discovered by Brandt of Hamburg in 1669, and named from *phos*, "light," and *pheirein* "to bear;" is obtained from bone-earth, or native phosphate of lime, which is decomposed by dilute Sulphuric Acid and the Phosphoric Acid mixed with $\frac{1}{4}$ its weight of powdered charcoal, and distilled. The P is thus deoxidized, and is collected in water. Great precaution is necessary in the distillation.

243. Phosphorus is a wax-like, nearly transparent, brittle, yet flexible substance, fusing at 110° , and boiling at 572° ; very combustible; exhales fumes in atmospheric air, which are luminous in the dark; is insoluble in water, but is soluble in Alcohol, Ether, oils, Bisulphide of Carbon and Chloride of Phosphorus, and from the latter liquids it is often deposited in octahedral and dodecahedral crystals; is very poisonous, but is nevertheless used cautiously in medicine; unites with the metals, &c., to form phosphides; is used chiefly in the manufacture of matches; requires to be kept under the surface of water; takes fire spontaneously in Cl and in the vapor of I or Br .

244. Amorphous *P*, i. e., phosphorus in an *allotropic* state, was discovered by Schrötter, and may be made by exposing common *P* for 50 hours to a temperature of about 470° F. in an atmosphere unable to act chemically upon it. It is a reddish-brown looking solid; insoluble in Bisulphide of Carbon, Terchloride of *P*, or Naphtha; does not take fire in air till heated to 500°; has a spec. grav. of 1.964; when heated above 500° it is reconverted into common Phosphorus.

COMPOUNDS OF PHOSPHORUS AND OXYGEN.

245. *P* forms four compounds with *O*, viz: Oxide of *P* = P_2O ; Hypophosphorous Acid = PO ; Phosphorous Acid = PO_3 ; Phosphoric Acid = PO_5 .

246. OXIDE OF PHOSPHORUS, P_2O , produced when *P* is placed in boiling water and a stream of *O* cast upon it, is an insoluble red powder which burns at about 600°.

247. HYPOPHOSPHOROUS ACID, PO , is very little known; it is formed when Phosphide of Barium is put into hot water; is a thick sour liquid; forms with bases Hypophosphites, which are all soluble in water. Hypophosphorous Acid has a great affinity for *O*, and is therefore a powerful deoxidizing agent.

248. PHOSPHOROUS ACID, PO_3 , is formed when *P* is burnt in rarefied air, or by acting on Terchloride of *P* by water; the acid crystallizes with 3 equiv. of water or becomes $3HO.PO_3$; is a powerful deoxidizing agent; unites with bases to form phosphites.

249. PHOSPHORIC ACID, PO_5 , is formed when *P* is burnt in *O* or in free air, or is obtained by decomposing phosphate of lime by Sulphuric Acid; in the anhydrous state it is a white uncry stallizable solid, fusible at a red heat and is then transparent; it is very deliquescent, and rapidly attracts moisture from the air; is very soluble in water; strongly acid; reddens vegetable blues, and unites to bases to form phosphates.

250. Phosphoric Acid forms three distinct hydrates which unite with bases forming distinct classes of phosphates. If we view them as compounds of Anhydrous Acid and water, then they are PO_5 , HO ; PO_5 , $2HO$; PO_5 , $3HO$. If, on the other hand, we view

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them as hydrogen acids, then they are quite distinct compounds, and their formulas will be PO_5H ; PO_5H_2 ; PO_5H_3 . Their names are as follows:

Protohydrated, Glacial, Metaphosphoric or Monobasic Phosphoric Acid, PO_5, HO_5, H .

Deutohydrated, Pyrophosphoric or Bibasic Phosphoric Acid, $PO_5, 2HO$ or $PO_5, 2H$.

Terhydrated, Common or Tribasic Phosphoric Acid, $PO_5, 3HO$ or $PO_5, 3H$.

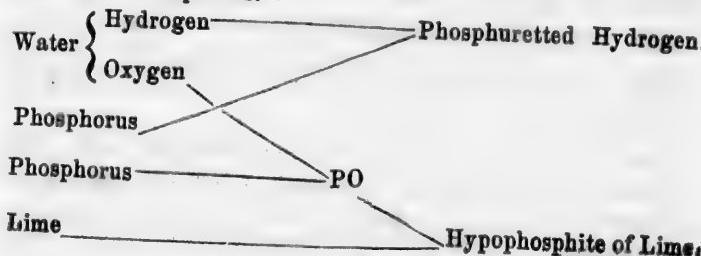
When Common or Tribasic PO_5 is heated for a long time to 417° it loses 1 equiv. of water, and becomes $PO_5, 2HO$ or Bibasic, and this heated to redness gives off another equiv. of water, and becomes PO_5, HO or Monobasic Acid.

251. The Monobasic Acid forms salts containing 1 equiv. of base to 1 of acid; the Bibasic Acid forms salts containing 2 equiv. of base to 1 of acid; and the Tribasic Acid forms salts containing 3 equiv. of base to 1 of acid.

COMPOUNDS OF PHOSPHORUS AND HYDROGEN.

252. PHOSPHURETTED HYDROGEN, Symb. PH_3 . This may be obtained by heating in a small retort hydrated Phosphorous Acid, which is, by such treatment, decomposed into Phosphuretted Hydrogen and hydrated Phosphoric Acid. Thus obtained, PH_3 has a spec. grav. of 1.24; possesses a highly disagreeable odor resembling that of garlic; is slightly soluble in water, and burns with a brilliant white flame, forming water and phosphoric acid.

253. PH_3 may also be obtained by boiling together in a retort of small dimensions Caustic Potassa or hydrate of lime, water and Phosphorus.



254. PH_3 , formed by the latter method is spontaneously inflammable when admitted into the air or into O . PH_3 exists in both a spontaneously inflammable state and a state not spontaneously inflammable. It is said that the first may be changed into the second by a small quantity of vapor of ether, oil of turpentine, &c., and the second into the first by the addition of a minute quantity of Nitrous Acid.

255. In reality there exists three compounds of P and H , viz :—1st. A fluid, P_5H_{10} ; 2nd. a solid, P_2H ; and 3rd. the gas, PH_3 . In the above process the fluid is first formed, and is spontaneously resolved into the other two, thus $P_5H_{10}=P_2H+3PH_3$. The gas PH_3 acquires its spontaneous combustibility by dissolving some of the liquid P_5H_{10} . This liquid renders any other combustible gas spontaneously inflammable.

256. PH_3 when kept for some time loses the property of being spontaneously inflammable, and the solid Phosphide of Hydrogen P_2H is deposited on the inside of the containing jar or bottle.

257. P unites with Chlorine by taking fire spontaneously in it, thus forming two compounds, PCl_3 and PCl_5 .

258. Tetrachloride of Phosphorus, PCl_3 , is formed when dry Cl acts on excess of P ; it is a transparent, colorless liquid, specific gravity 1.450, boils at 173°; fumes in the air, and has a suffocating odor; is rapidly decomposed by water— HCl and $PO_3,3HO$ being produced.

259. Pentachloride of $P=PCl_5$ is formed when Cl in excess acts on P . The latter burns, and produces a white solid; volatile at 200°; fumes in the air; is decomposed by water, and resolved into HCl and $PO_5,3HO$.

260. P and N form a compound PN_2 .

261. P forms compounds with I and Br , which are analogous to those it forms with Cl .

262. When P and S are heated together under water, they combine and form several compounds which are exceedingly inflammable, and have a strong tendency to explode violently when heated.

LECTURE XIII.

SILICON.

263. SILICON, Symb. *Si*; Equiv. 21.3; was discovered by Berzelius in 1824, and named from its being the chief constituent of silex or flint. *Si* is prepared by igniting the Silico-fluoride of Potassium with Potassium; water dissolves off the Fluoride of Potassium, and leaves the *Si* as a nut-brown powder. *Si* is infusible; has neither taste nor smell; burns in the air or in *O* when strongly heated, and forms Silica; *Si* exists in an allotropic form which is not combustible.

264. *Si* unites with *O* to form Silicic Acid or Silica, SiO_3 . This is one of the most abundant substances in nature; exists pure in rock crystal, flint, quartz, agate, jasper, heliotrope, cornelian (the three latter colored by oxide of *Fe*), amethyst (colored by oxide of *Mn*), opal, and chalcedony (with water). Many sands and sandstones are nearly pure Silica or Silicic Acid.

265. SiO_3 is obtained pure by decomposing an alkaline silicate by means of Hydrochloric Acid, and washing and drying the precipitate; is a snow-white powder; is insoluble in water and all acids except Hydrofluoric Acid; fusible at a white heat, and may be drawn into threads; spec. grav. 2.600; with alkalies and alkaline earths it forms silicates, all of which, except those containing an excess of the stronger alkalies, are insoluble in water. The greater number of rocks and minerals consist of silicates, especially those of alumina, lime, magnesia, oxide of iron, potash, and soda. The silicates of potash and soda, when heated to redness, form glass, which is insoluble in water if the acid is in excess, but very soluble if the alkali predominates. SiO_3 enters largely into the composition of many vegetables, and to some extent to that of all—also in animals.

266. Silicon and *F* unite to form Fluosilicic Acid Gas, SiF_4 . It may be formed by a mixture of Fluoride of Calcium, Silica and Oil of Vitriol; is a transparent, colorless gas, which may be

collected over mercury ; spec. grav. 3·600 ; fumes in the air, is strongly acid, and is instantly decomposed by water, being resolved into Hydrofluoric Acid, gelatinous Silica, and Hydro-fluosilicic Acid.

LECTURE XIV.

SELENIUM.

267. SELENIUM, Symbol *Se*; Equiv. 40; was discovered by Berzelius in the year 1818, and was named from *selene*, “the moon.” Selenium is a reddish brown solid body, with a semi-metallic lustre, and having a spec. grav. of about 4·300. It melts at 482°, and boils at 1292°; is insoluble in water, and exhales, when heated in the air, a peculiar odor resembling that of horse-radish. It forms with *O* two acids, viz., SELENIUS ACID, SeO_2 , and SELENIC ACID, SeO_3 . It also unites with *H*, *S*, *P*, *Cl*, *Br* and *I*. With *H* it forms Hydroselenic Acid or Selenu-retted Hydrogen, a deadly poisonous gas which inflames the eyes, and for some hours destroys the sense of smell.

In all its chemical relations Selenium bears a very strong and remarkable resemblance to Sulphur.

BORON.

268. BORON, Symbol *B*; Equiv. 11; was discovered simultaneously by Davy, Gay Lussac, and Thénard, and was named from its being the peculiar principle in Borax (Arabic *buruk*), which is a borate of soda.

269. Boron exists native in Boracic Acid, and is obtained from anhydrous Boracic Acid by ignition with Potassium, which decomposes the acid, abstracting the *O*. Thus obtained, it is an amorphous brownish olive-green powder, having neither taste nor smell. It is insoluble in water ; has a spec. grav. of 2·000 ; and when heated in air or in *O* it burns, forming Boracic Acid. Boron has also lately been obtained in two crystalline forms, bearing a close resemblance to diamond and graphite.

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270. DIAMOND-BORON, as obtained in the laboratory, is a honey-yellow, or a garnet-red transparent crystalline body, in lustre and refractive power scarcely inferior to the diamond, is one of the hardest bodies known; scratches corundum and even the diamond itself; withstands the heat of the oxy-hydrogen blow-pipe, and is but slightly acted upon by O at the temperature at which the diamond burns.

271. GRAPHITOIDAL BORON exists in opaque laminæ, which are frequently hexagonal. They have a slightly reddish color, and possess the form and lustre of native graphite or plumbago.

272. BORACIC ACID, BO_3 , as obtained from borax by the action of Sulphuric Acid, is a white crystalline solid, having a composition of $BO_3 \cdot 3HO$. By a red heat the 3 equiv. of water are expelled, and the anhydrous acid obtained. This has a weak taste, being scarcely at all acid; it is slightly soluble in water, but more so in Alcohol, the flame of which it tinges green.

273. Boracic Acid unites with bases to form borates, which are all, with the exception of the alkaline borates, only slightly soluble in water, and which, fused before the blow-pipe, possess the property of dissolving many metallic oxides.

LECTURE XV.

THE METALS.

274. THE METALS are defined to be those bodies (about 50 in number) which possess the peculiar appearance called the *metallic lustre*, and which are capable of conducting, with facility, both heat and electricity. In other respects, they differ from one another very greatly.

275. Their COLOR is generally white, variously tinged from pink to blue. Three are strikingly colored, viz., Gold, which is yellow; and Copper and Titanium, which are red.

276. Their SPECIFIC GRAVITY varies from 0.598 (Lithium) and 0.865 (Potassium), to 21.530 (Platinum).

277. In **HARDNESS** they differ very widely. Potassium and Sodium are so soft that they may be kneaded by the fingers ; Lead, Silver, and Tin may be cut with a knife ; Iron, Nickel, and Antimony are much harder, and Iridium is one of the hardest of known bodies.

278. **MALLEABILITY AND DUCTILITY.**—Some metals, as Antimony, Bismuth, and Cobalt, are brittle, i. e., if hammered, they break to powder ; others, as Tin, Copper, Silver, Platinum, Palladium, and Gold, may be hammered out into very thin sheets (57 sq. inches of the finest gold leaf weigh only one grain). The most ductile metals are Copper, Palladium, Iron, Silver, Gold, and Platinum (a single grain of Gold may be drawn out into a wire of 550 feet in length, and a grain of Platinum, which is six times more ductile, may be drawn into a wire of 3,300 feet in length).

279. **TENACITY.** The tenacity of metals is determined by comparing the weight which wires of equal diameters, but of different metals, will sustain. It has been ascertained that wires having a diameter of about $\frac{1}{100}$ of an inch, have a tenacity as follows :

Iron wire supports 550 lbs.		Gold wire supports 150 lbs.
Copper " 302 "		Zinc " 110 "
Platinum " 274 "		Tin " 35 "
Silver " 187 "		Lead " 28 "

280. **FUSIBILITY.**—Mercury is liquid at all temperatures between -39° , and $+660^{\circ}$, Potassium fuses at 150° , Sodium at 194° , Tin at 442° , Lead at 612° , Copper at 1996° , Gold at 2016° , Iron, at 2786° , while Platinum and some others require the intense heat of the oxy-hydrogen blowpipe to melt them.

281. **VOLATILITY.**—The metals, in general, are highly fixed bodies, but it is probable that all of them may be volatilized at the highest temperatures. Mercury is slowly dissipated in vapor at all temperatures above 68° , and boils at 660° . Mercury, Cadmium, Arsenic, Tellurium, Zinc, Potassium, and Sodium, are all converted into vapors at a temperature varying from a low to a bright red heat, and are occasionally distilled, from the facility with which they are volatilized.

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CLASSIFICATION OF THE METALS.

282. The metals have been separated into eight classes, which are distinguished from one another, chiefly by the facility with which they decompose water, and the effect of heat in reducing their oxides.

CLASS I.—METALS OF THE ALKALIES PROPER.

These metals decompose water even at 32°, with hissing effervescence, and usually with flame; they are rapidly oxidized on exposure to the air; their oxides are powerful bases, and are very soluble and very caustic. They are :

Potassium, Sodium, Lithium, Ammonium ?

CLASS II.—METALS OF THE ALKALINE EARTHS.

These have also a very strong affinity for Oxygen, and, except Magnesium, they decompose water at ordinary temperatures, but without flame. Their oxides are powerful bases, but are less soluble, and less caustic than those of class I. They are :

Barium, Strontium, Calcium, Magnesium.

CLASS III.—METALS OF THE EARTHS PROPER.

These metals do not decompose water at ordinary temperatures, but do so much below a red heat. They burn in the air, when heated, and form oxides which are less powerful bases than those of classes I and II, and which, being earthy in aspect, and quite insoluble, are called *earths*. They are :

Aluminum, Yttrium, Zirconium, Glucinium,
Thorium, Erbium, Terbium.

CLASS IV.—METALS PROPER, OF WHICH THE PROTOXIDES ARE ISOMORPHOUS WITH MAGNESIA.

These do not decompose water except at a red heat, or at ordinary temperatures in the presence of strong acids. They are :

Iron, Nickel, Cobalt, Zinc,
Cadmium, Lead, Manganese, Copper.

CLASS V.—OTHER METALS PROPER HAVING ISOMORPHOUS RELATIONS WITH THE MAGNESIAN FAMILY.

These do not decompose water at any temperature, nor in the presence of the strong acids. They do, however, at a red heat decompose the *vapor* of water with considerable effervescence. They are :

Tin,	Chromium,	Vanadium,	Tellurium,
Tungsten,	Molybdenum,	Titanium.	

CLASS VI.—METALS ISOMORPHOUS WITH PHOSPHORUS.

These even at a bright red heat decompose water very feebly, but their oxides, once formed, cannot be reduced to the metallic state by heat alone. They are :

Arsenic,	Antimony,	Bismuth.
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CLASS VII.—THE NOBLE METALS.

These do not decompose water under any circumstances, their affinity for Oxygen is so feeble that they do not rust or tarnish on continued exposure to the air, and their oxides are reduced by a high temperature. They are :

Silver,	Palladium,	Iridium,
Mercury,	Platinum,	Rhodium,
Gold,	Osmium,	Ruthenium.

CLASS VIII.—METALS PROPER NOT INCLUDED IN THE FOREGOING CLASSES, AND WHOSE OXIDES ARE NOT REDUCIBLE BY HEAT ALONE:

Uranium,	Lanthanum,	Tantalum,	Niobium,
Cerium,	Didymium,	Ilmenium,	Pelopium.

NOTE.—The remaining metals, Aridium, Donarium, and Norium, are not sufficiently known to enable us to determine in what class they fall.

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LECTURE XVI.

COMPOUNDS OF METALS WITH METALLOIDS AND
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METALLIC OXIDES.

283. Metals combined with oxygen form three classes of oxides, which with their general formulas are as follows :—

I.—BASIC METALLIC OXIDES.

Name.	General Formula.	Examples.
Suboxide,	M_2O	Cu_2O
Protoxide,	MO	CuO, FeO, HgO, VO, AgO
Sesquioxide,	M_2O_3	$Fe_2O_3, Co_2O_3, Mn_2O_3, Au_2O_3, Os_2O_3$

II.—NEUTRAL METALLIC OXIDES.

.....	M_3O_4	$Pb_3O_4, Mn_3O_4, Fe_3O_4$
Binoxide,	MO_2	$PbO_2, BiO_2, MnO_2, PtO_2, VO_2$

III.—ACID METALLIC OXIDES.

Binoxide,	MO_2	Titanic Acid TiO_2 , Stannic Acid SnO_2
Teroxide,	MO_3	Chromic Acid CrO_3 , Ferric Acid FeO_3 ,
		Arsenious Acid AsO_3
.....	M_2O_7	Permanganic Acid Mn_2O_7
Quadroxide,	MO_4	Osmic Acid OsO_4
Pentoxide,	MO_5	Arsenic Acid AsO_5 ; Antimonic Acid SbO_5

REDUCTION OF THE METALLIC OXIDES.

284. The metallic oxides are deprived of their oxygen, and are thus reduced to the metallic state by different methods.

- I. The oxides of the noble metals, or those in Class VII, are reduced by a red heat alone.
- II. Many oxides, as, for example, those of Copper, Iron, Tin, Potassium, Barium, &c., are reduced by the joint action of heat and deoxidising agents.

NOTE.—A deoxidising agent is a body whose affinity for oxygen is so strong that it withdraws it, under certain circumstances, from the oxide. Carbon, Hydrogen, Carbonic oxide, &c., are deoxidising agents, but the most powerful are the formiates and Cyanide of Potassium. The mode in which the simple reducing agents *C* and *H* act is as follows:—



- III. The oxides of several metals can be reduced only by means of a powerful galvanic battery. When reduced by this mode the metal always appears at the negative pole of the battery.
- IV. Certain oxides in solution are precipitated in the metallic state by other metals which have a stronger affinity for the oxygen. Thus, copper precipitates silver, and iron precipitates copper.

METALLIC CHLORIDES.

285. The metallic chlorides are also reduced by several methods, as by heat alone; by the action of another metal for which the chlorine has a greater affinity; by the action of hydrogen; by boiling with a formiate, &c.

METALLIC SULPHIDES.

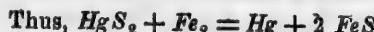
286. The metallic sulphides are reduced—

I. By roasting them in the air, by which means the sulphur is converted into Sulphurous Acid, and the metal into oxide, which latter is reduced by being again heated with charcoal.

II. By heating to redness in an atmosphere of hydrogen.



III. By roasting with another metal.



IV. By heating with Cyanide of Potassium or with one of the formiates. Thus, Tersulphide of Arsenic roasted with Formiate of Soda.



ALLOYS.

287. The compounds of metals with metals are called alloys, except when mercury is present, when they are termed amalgams. The principal alloys are the following :—

FINE SOLDER = 2 parts tin + 1 part lead. It melts at 360° .

COARSE SOLDER = 1 part tin + 3 parts lead. It melts at 500° .

PEWTER = tin + small quantities of antimony, copper, and bismuth. The inferior kinds contain more or less lead.

NEWTON'S FUSIBLE METAL = 8 parts bismuth + 5 parts lead + 3 parts tin. It melts below 212° .

ROSE'S FUSIBLE METAL = 2 parts bismuth + 1 part lead + 1 part tin. It melts at 200° .

FUSIBLE METAL = 248 parts bismuth + 155 parts lead + 90 parts tin + 13 parts mercury. This composition melts at 162° .

TYPE METAL = 3 parts lead + 1 part antimony + a small quantity of tin.

BRONZE = 90 parts copper + 10 parts tin.

BELL METAL AND GONG METAL = 80 parts copper + 20 parts tin.

SPECULUM METAL = 2 parts copper + 1 part tin + a little arsenic.

BRASS = 4 parts copper + 1 part zinc. When the proportion of zinc is increased we have tombac, Dutch gold, and pinchbeck.

GERMAN SILVER = 100 parts copper + 60 parts zinc + 40 parts nickel. The inferior kinds are deficient in nickel.

TIN AMALGAM = tin + mercury, is used for silvering the backs of mirrors.

ELECTRIC AMALGAM = 2 parts zinc + 1 part tin + 6 parts mercury.

SALT-RADICAL THEORY.

288. A salt has been defined to be "a compound of an acid with a base," and according to this definition the compounds of Chlorine, Iodine, Bromine, and Fluorine, with the metals, are not salts. Since, however, these bodies possess in a very high degree the saline characters, it was formerly thought necessary to separate salts into two distinct classes :

1st. *Oxy-salts*, or those which consist of oxygen-acids combined with bases.

2nd. *Haloid salts*, or those which consist of a metal united to a salt-radical after the type of common salt (*Hals* "sea-salt," *eidos* "form").

289. We have seen that a radical is any body simple or compound which is capable of chemically uniting with an elementary body. A *salt-radical* may be defined to be a body (either simple like Chlorine or compound like Cyanogen) which forms an *acid* with *hydrogen* and a *salt* with *sodium* or any other metal.

290. The salt-radical theory assumes that all salts are binary compounds, being produced by the union of a metal with a simple or compound salt-radical.

291. The following exhibits the changes in nomenclature and notation that the adoption of this theory would render necessary.

ON THE ACID THEORY.

Hydrated sulphuric acid, sulphate of oxide of hydrogen or hydric sulphate,.....	$HO+SO_3$
Sulphate of potash, sulphate of oxide of potassium or potash sulphate,.....	$KO+SO_3$
Hydrated nitric acid, nitrate of oxide of hydrogen or hydric nitrate,.....	$HO+NO_3$
Nitrate of potash, nitrate of oxide of potassium or potash nitrate,.....	$KO+NO$
Chloride of hydrogen or hydrochloric acid,.....	$H+Cl$
Chloride of potassium,.....	$K+Cl$
Cyanide of hydrogen or hydrocyanic acid,.....	$H+C_2N$
Cyanide of potassium,.....	$K+C_2N$

ON THE SALT-RADICAL THEORY.

Sulphionide of hydrogen or hydrosulphuric acid,..	$H+SO$
Sulphionide of potassium,.....	$K+SO$
Nitrationide of hydrogen or hydronitranic acid,...	$H+NO_2$
Nitrationide of potassium,.....	$K+NO_2$

Chloride of hydrogen or hydrochloric acid,	$H + Cl$
Chloride of potassium,	$K + Cl$
Cyanide of hydrogen or hydrocyanic acid,	$H + C_2N$
Cyanide of potassium,	$K + C_2N$

292. The advantages of the salt-radical theory are the following :—

- I. It makes but one class of salts instead of two classes.
- II. It affords a more simple and philosophical explanation of the action of certain metals upon acid solutions.
- III. It accounts for the remarkable law that to produce neutral salts "Bases always combine with as many atoms of acid as they themselves contain of oxygen," i. e., a protoxide forms a neutral salt with one atom of an oxygen-acid, a sesquioxide, with three atoms of an oxygen-acid; a binoxide, with two atoms of an oxygen-acid, &c.

Thus, the neutral sulphates of a metal are constituted as follows :—

OLD VIEW.	NEW VIEW.
$M_2O + SO_3$	$M_2 + SO_4 =$ Subsulphionide.
$MO + SO_3$	$M + SO_4 =$ Protosulphionide.
$M_2O_3 + 3SO_3$	$M_2 + 3SO =$ Sesquisulphionide.
$MO_2 + 2SO_3$	$M + 2SO_4 =$ Bin sulphionide.

These sulphionides correspond to the known chlorides, M_2Cl , MCl , M_2Cl_3 , and MCl_2 .

NOTE.—There are, however, certain strong objections to the salt-radical theory, which must, until they are removed, prevent its general adoption.

METALS OF THE ALKALIES PROPER.

LECTURE XVII.

POTASSIUM.

293. POTASSIUM (alium), Symb. K ; Equiv. 39; Spec. Grav. 0.865; was discovered in the year 1807, by Sir H. Davy, as a constituent of potash which is Oxide of Potassium.

Potassium is a bluish white metal, so very oxidizable that it can be preserved only in fluids or gases containing no oxygen; is commonly preserved in the hydrocarbon mineral naphtha.—Potassium is brittle and crystalline at 32° ; is soft like wax at ordinary temperatures; melts at 150° , and boils at a red heat, forming a green vapor. When melted under the surface of naphtha, Potassium exhibits a high degree of metallic lustre, but it tarnishes instantly on exposure to the air. When heated to dull redness in the air, or when thrown upon the surface of water, it takes fire, burns with a beautiful violet colored flame, and is converted into Potassa, or the Oxide of Potassium. Potassium is distinguished above all other bodies by its intense affinity for oxygen. Potassium is the characteristic alkali of the vegetable kingdom, as Sodium is of the animal kingdom. It exists as a constituent of most rocks (feldspar contains 12 per cent.), is obtained as potash by lixiviating the ashes of plants. Metallic Potassium is obtained from the Carbonate of Potash, by decomposing it by the joint action of heat and charcoal.

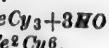
294. The principal compounds of Potassium are :

Protoxide of potassium,	<i>KO.</i>	Protosulphide of potassium	<i>KS.</i>
Peroxide of	" <i>KO₂.</i>	Pentasulphide of	" <i>KS₅.</i>
Chloride of	" <i>KCl.</i>	Ferrocyanide of	" <i>K²FeCy₃+3HO</i>
Iodite of	" <i>KI.</i>	Ferridecyanide of	" <i>K³Fe²Cy₆.</i>
Bromide of	" <i>KBr.</i>	Cyanide of	" <i>KCy.</i>

295. PROTOXIDE OF POTASSIUM, POTASH, OR POTASSA, Symb. *KO* = 47; is a white powder which rapidly absorbs water from the air, and becomes common or caustic potash, which is *KO.HO*. Caustic potash is obtained by decomposing the Carbonate of Potash by lime. It is a semi-crystalline solid; has a specific gravity of 1.700; is fusible at 700° ; is very deliquescent; is soluble in water and in alcohol; its solution (*aqua potassa*) is caustic, and highly alkaline. Caustic potash is much used in medicine as a cauterizer.

296. IODIDE OF POTASSIUM, *KI*, is obtained by dissolving iodine in a solution of potassa until the mixture is neutral. This mixture, consisting in part of *KI*, and in part of *KO.IO₅*, is evapo-

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rated to dryness, and then heated to redness in order to decompose the KO_2IO_5 . Iodide of Potassium crystallizes in cubes or prisms which are white and opaque. It has an alkaline reaction owing to the presence of a small quantity of KO_2CO_3 ; is soluble in water, and to a less degree in alcohol; is not poisonous even in doses of several drachms; is much used in medicine, and its solution is employed as a solvent for iodine—30 grains of KO and 20 grains of iodine being usually dissolved in one ounce of water. The solution of bromide also dissolves Bromine, but that of chloride has no affinity for Chlorine. Both the iodide and bromide are extensively employed in photography. Chloride of Potassium has a taste like that of common salt, which it also resembles in most other respects. It is principally consumed in the manufacture of alum.

297. FERROCYANIDE OF POTASSIUM, or yellow-prussiate of potassa, is produced by exposing Carbonate of Potash mixed with dry blood, horns, clippings of hoofs or hides, or other animal matters, to a red heat in an iron pot. It is a lemon-yellow colored salt crystallized in quadrangular tables with truncated angles and edges; soluble in 4 parts of cold and in 2 parts boiling water; insoluble in alcohol, has a saline taste, and is not poisonous.

298. FERRIDCYANIDE OF POTASSIUM, or red prussiate of potassa, symb. $K_3Fe_2Cy_6$ or $3K+2(FeCy_3)$ is obtained by treating a solution of Ferrocyanide of Potassium with chlorine gas until it ceases to give a precipitate of prussian blue with a persalt of iron. The mixture contains chloride and ferridcyanide, and the latter is separated by crystallization. Ferridcyanide of Potassium is a transparent red salt, crystallized in anhydrous rhombic prisms; soluble in about 4 parts of cold water; is, in solution, a delicate test for iron, which it throws down as prussian blue.

299. CYANIDE OF POTASSIUM, KCy , is obtained with difficulty from Ferrocyanide of Potassium. It is a colorless salt crystallized in cubes; in contact with air becomes Cyanate of Potassa; is similar in its action on the animal economy to Hydrocyanic Acid, and is often employed as a source of Hydrocyanic Acid of known strength; thus, 24 grains pure Cyanide of Potassium 56 grains

of Tartaric Acid and one ounce of water agitated together in a stout phial closed by a cork and afterwards filtered, gives a solution of 10 grains of Hydrocyanic Acid in 1 ounce of water, or rather more than 2 per cent.

300. THE SULPHIDES OF POTASSIUM are K_2S , K_2S_2 , K_2S_3 and K_2S_5 and an impure sulphide called *Hepar Sulphuris*, or liver of sulphur. This last is sometimes employed in medicine, and is prepared by fusing a sulphur with Carbonate of Potassa. Its composition of course varies with the proportion in which the ingredients are employed, but it is always a mixture of one or more of the above sulphides with hyposulphite and Sulphate of Potassa.

301. The principal salts of Potash are the following :

Nitrate of potash,.....	KO, NO_5 .	Acetate of potash,..	$KO, C_4H_3O_3$.
Carbonate of potash,.....	KO, CO_2 .	Oxalate of potash,..	KO, C_2O_3+HO .
Bicarbonate of ".....	KO, CO_2+KO, CO_3	Tartrate of potash,..	$2KO, C_6H_4O_{10}$.
Sulphate of potash,.....	KO, SO_3 .	Urate of pot.,	$KO, HO, C_{10}H_2N_4O_4$.
Chlorate of potash,.....	KO, ClO_5 .	Cyanate of potash,..	KO, CyO .

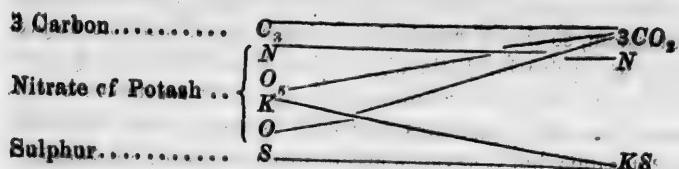
302. NITRATE OF POTASH, KO, NO_5 , is called also Nitre or Saltpetre. It is a white crystalline solid, having a specific gravity of 1.933; is very soluble in water, and not at all soluble in absolute alcohol; is used as a source of Nitric Acid, as a manure, and also for curing meat, owing to its antiseptic properties. It is likewise employed in the manufacture of gunpowder, which is very nearly C_3SNit .

COMPOSITION OF GUNPOWDER.

Theoretical Mixture.	English.	French.
Sulphur.....	11.9.....	12.5.....
Charcoal.....	13.5.....	12.5.....
Nitre.....	74.6.....	75.0.....
	100.0	100.0
		100.0

When gunpowder is fired, the results are Carbonic Acid, Nitrogen, and Sulphide of Potassium. Thus:

DEFLAGRATION OF GUNPOWDER.



In the explosion of gunpowder the nitre is decomposed by the charcoal, the sulphur merely accelerating the process of deflagration, and supplying heat. One cubic inch of good powder yields about 800 cubic inches of cold gas, and as at the moment of explosion the gas is red hot, we may safely reckon the expansion as about 1 into 2000. Gunpowder may be analyzed by

- 1st. Boiling in water to remove the nitre ; and
- 2nd. Exposing the residue to a tolerably strong heat to vaporize the sulphur.

NOTE.—It is essential to the propelling force of gunpowder that its explosion, though occupying only an exceedingly short space of time, should not be absolutely instantaneous. Fulminating mercury and other explosive compounds that burn more rapidly than gunpowder are not adapted to the propulsion of projectiles, since, if substituted for powder, they shatter the gun, but do not project the ball.

303. CARBONATE OF POTASH, in an impure state, forms the potashes and pearlashes of commerce. It is a white, fusible, highly alkaline solid, which crystallizes with 2 equiv. of water. It is very soluble in water, and its solution feels greasy to the touch.

LECTURE XVIII.

SODIUM.

304. SODIUM (Natrium) Symb. *Na*; Equiv. 23; Spec. Grav. 0.934; was discovered by Davy, in the year 1808, in soda, which is the protoxide of the metal. Sodium is, with the exception of Aluminum and perhaps Potassium, the most abundant metal on the globe; it constitutes two-fifths, by weight, of salt, and exists as an oxide in many minerals.

Sodium is obtained in a metallic state much more easily than Potassium, so that if required on a large scale, it might be prepared at a price but little higher than that of zinc. Sodium is a brilliant yellowish white metal; in color resembles silver, while Potassium resembles mercury; is not quite as oxidizable as Potassium, but it nevertheless tarnishes instantly on exposure to the air, and must be preserved in naphtha; is the characteristic alkali of the animal kingdom, its salts being found in all animal fluids; is so soft at ordinary temperatures that it yields to the pressure of the finger; it does not become brittle at 32° ; it melts at 194° , and boils at a red heat, forming a colorless vapor. It burns in the air with a bright yellow flame, and decomposes water with lively effervescence, but not with flame unless the water be hot or in the form of ice, or be rendered thick and viscid by gum or starch.

305. Sodium forms numerous compounds with the metalloids, which, generally speaking, very closely resemble the corresponding Potassium compounds. The only compounds of Sodium that are of much interest are the protoxide and the chloride.

306. CHLORIDE OF SODIUM, Symb. Na, Cl , is the common or kitchen salt, and was formerly incorrectly called *muriate of soda*. It occurs native abundantly as rock salt in beds which are found in geological formations posterior to the coal. The most celebrated salt mines are those of Cheshire and Gloucestershire in England, Salzburg in Switzerland, Cordova in Spain, and Wielitska in Poland; the last named is of enormous extent, and is capable of supplying the entire world for ages. Salt is also largely obtained by the evaporation of sea-water, which contains about 2·7 per cent. of Chloride of Sodium.

Salt is a white solid; crystallizes in cubes without water; is not deliquescent when pure; decrepitates when heated, owing to the water between the plates, or to unequal expansion; is fusible at a red heat, and volatile at a white heat; has a spec. grav. of 2·125; is very soluble in water, and but slightly more so in hot than in cold water; is not soluble in alcohol. By the action of Sulphuric Acid salt yields Hydrochloric Acid and Sul-

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phate of Soda. It is much used as an antiseptic in curing meats; is extensively employed as a condiment, and seems to be essential to the healthy functions of the animal economy, giving Hydrochloric Acid to the gastric juice, and soda to the bile; is valuable as a source of soda and its salts, also Chlorine and Hydrochloric Acid; is employed in agriculture as a manure, and is used as a flux in the manufacture of earthenware.

307. SODA, NaO , is a white powder, which rapidly attracts moisture from the air, and becomes hydrated oxide of sodium commonly called caustic soda, which is $NaO \cdot HO$.

CAUSTIC SODA is a white semi-transparent brittle deliquescent solid, which closely resembles caustic potash. It is fusible at a red heat, and is decomposed by a white heat. It unites with acids to form salts which are similar to those of potash, but which are distinguished from them and indeed from those of all other bases, by their greater solubility, and by their communicating a rich yellow tint to flame.* The principal salts of soda are the following :—

Carbonate of soda,.....	$NaO \cdot CO_2 + 10HO$
Bicarbonate of soda,.....	$HO \cdot CO_2 + NaO \cdot CO_2$
Sulphate of soda,.....	$NaO \cdot SO_3 + 10HO$
Sulphite of soda,.....	$NaO \cdot SO_2$
Hypocupphite of soda,.....	$NaO \cdot S^2 O^2 + 5HO$
Nitrate of soda,.....	$NaO \cdot NO_3$
Biborate of soda,.....	$NaO_2 BO_3 + 10HO$
Tribasic phosphate of soda,.....	$HO_2 NaO \cdot PO_5 + 24HO$
Pyrophosphate of soda,.....	$2NaO \cdot PO_5 + 10HO$
Metaphosphate of soda,.....	$NaO \cdot PO_5$
Hypo-chlorite of soda,.....	$NaO \cdot ClO$
Microcosmic salt is a tribasic phos- phate of soda, ammonia, and water, =	$NaO \cdot HO \cdot NH_4 \cdot O \cdot PO_5 + 8HO$

308. CARBONATE OF SODA, $NaO \cdot CO_2 + 10HO$ is the soda of commerce; $NaO \cdot CO_2$ also crystallizes with HO , $5HO$, $6HO$, and $8HO$. The common carbonate is much used as a source of the other soda salts, and in the manufacture of soap and glass. *Trona* is a native Sesquicarbonate of Soda.

* The salts of potash impart a pink or violet tint to flame; and those of strontia a red tint.

309. SULPHATE OF SODA, Glauber's salt, exists native in Spain, Switzerland, and elsewhere in mineral springs. **NITRATE OF SODA,** or cubic nitre, is found abundantly in the soil in certain parts of South America. It cannot be substituted for saltpetre in the manufacture of gunpowder on account of its hygrometric nature. **BORAX,** or borate of soda, exists native in India and Persia, and is extensively employed in blowpipe experiments as also is microcosmic salt. **SULPHITE OF SODA** is much employed in analysis as a deoxidizing agent and by calico-bleachers as an *antichlore*. **THE TRIBASIC PHOSPHATE,** or common phosphate, $2NaO, HO, PO_3$, is used medicinally and is employed in analysis as a reagent. There are two other tribasic phosphates, viz.: the subphosphate $3NaO, PO_3 + 2HO$ and the acid phosphate $NaO, 2HO, PO_3 + 2HO$. There is also a second bibasic salt—the acid pyrophosphate NaO, HO, PO_3 .

LITHIUM AND AMMONIUM.

310. LITHIUM is the metallic base of a very rare alkaline oxide known as lithia which is found in small quantities in certain minerals as lepidolite, petalite, &c. Its salts bear a close resemblance to those of potassa and soda, and are distinguished by their tinging the flame of the blow-pipe of a red color.

311. AMMONIUM is as before stated a strictly hypothetical body as also is its oxide NH_4O . By the action of the voltaic pile a very peculiar amalgam of ammonium is formed with mercury during the electrolysis of ammonia, but it is instantly decomposed by disconnection with the battery. Moreover the salts produced when ammonia is acted upon by the hydracids are precisely analogous to the corresponding salts of potassa and soda.

METALS OF THE ALKALINE EARTHS.

LECTURE XIX.

CALCIUM.

312. CALCIUM, Symb. Ca; Equiv. 20; Spec. grav. 1.578, was discovered by Davy in the year 1808, in lime, which is the protoxide of the metal. The element was named calcium from *calx* "burnt earth," a term long applied to lime.

Calcium is a yellowish-white very oxidizable metal ; is very malleable ; is softer than gold ; is fusible at a red heat ; when heated in the air it burns with a brilliant white light with scintillations ; it also burns with vivid light in chlorine, bromine, iodine, or sulphur vapor. It decomposes water, and readily amalgamates with mercury.

313. The principal compounds of calcium are—

Lime or protoxide of calcium,.....	<i>CaO</i>
Chloride of calcium,.....	<i>CaCl</i>
Fluor-spar or fluoride of calcium,.....	<i>CaF</i>
Sulphide of calcium.....	<i>CaS</i>

314. PROTOXIDE OF CALCIUM, OR LIME, Symb. *CaO*, is obtained by roasting the carbonate, and thus expelling the carbonic acid as in the process of lime-burning. Lime is a greyish-white solid ; has a spec. gravity of 3.08 ; is not fusible except at a very high temperature ; slowly volatilizes at a white heat ; is remarkably luminous when ignited in the flame of the oxy-hydrogen blowpipe, and is hence used in the Drummond light. It is a distinctly alkaline earth, caustic and acrid ; is a powerful base ; moistened with water, it swells, becomes very hot, and falls to a dry powder, forming a protohydrate *CaO+HO*, which is called *slaked lime*. Lime is more soluble in cold than in hot water ; one part of lime requires 750 parts of water at 60° or 1280 parts of water at 212° to dissolve it. The *milk* or *cream* of lime is merely the hydrate diffused through water.

Lime is applied to a number of useful purposes. It is of very great service, as the chief ingredient of mortars and as an agri-

cultural fertilizer. As a manure it oxidises and decomposes the insoluble organic matters found in the soil ; it decomposes clay and renders its potassa soluble, and it restores to the soil the calcareous matter carried off by the crop. As a mortar it is mixed with two or three parts of sand and made into a paste with water. The mortar particles at first cohere by the attraction of aggregation, but by degrees the mortar absorbs carbonic acid, and the lime passes into the state of carbonate.

Hydraulic lime or hydraulic cement is made by burning together limestone and clay.

315. The principal salts of lime are the following :—

Carbonate of lime.....	CaO, CO_2	Phosphate of lime....	CaO, PO_3
Sulphate of lime.....	CaO, SO_3	Hypochlorite of lime.	CaO, ClO

316. CARBONATE OF LIME, CaO, CO_3 , exists native abundantly as limestone, chalk, marl, marble, calcareous spar, arragonite, shells, corals, &c.

Carbonate of lime is insoluble in pure water, but is freely taken up in water containing carbonic acid. Since most river and spring waters contain carbonic acid, they also contain carbonate of lime which is deposited when the water is boiled or exposed to the air so as to part with the carbonic acid ; in the former case it constitutes the *fur* of kettles and boilers, and in the latter case the stalactites, stalagmites, and other calcareous formations of caves, &c. Carbonate of lime is decomposed by all acids except hydrocyanic ; is much used as a source of *quick* or *caustic* lime, as a manure, as a flux, as a building material, &c.

317. SULPHATE OF LIME, Symb. CaO, SO_3 ; Spec. Grav. 3.000 ; is not very soluble in water, one part of CaO, SO_3 requiring 500 parts of water to dissolve it. Gypsum is the native hydrate of the sulphate, symb. $CaO, SO_3 + 2HO$, and when this is kept heated for some time to about 280° it loses the two equiv. of water and becomes plaster of Paris, the setting of which depends upon the re-absorption of these two equiv. of water. Anhydrite is native sulphate of lime crystallized without water : selenite

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is crystallized hydrated gypsum. All the varieties of gypsum are most valuable manures, and plaster of Paris is used for building and other purposes.

A small portion of sulphate of lime dissolved in water renders it *permanently* hard, since we possess no available means of remedying the hardness; while the hardness produced by carbonate of lime is called *temporary*, because it is removed to a great extent by boiling or by mixing with lime water.

318. PHOSPHATE OF LIME.—There exist several distinct phosphates of lime, the tribasic phosphates being—

- I. $3CaO, PO_5$
- II. $2CaO, HO, PO_5$
- III. $CaO, 2HO, PO_5$

The phosphate of lime found in bones appears to be a mixture of the first two of these salts. The first phosphate also occurs native in combination with fluoride of calcium in the mineral Apatite which is $CaF + 3(3CaO, PO_5)$

319. HYPOCHLORITE OF LIME, Chloride of Lime, Bleaching Powder, Symb. $CaCl + CaO, ClO$, is a mixture of chloride and hypochlorite of lime. It is formed by exposing pure hydrate of lime to the action of chlorine, thus :—



The bleaching powder of commerce, if newly prepared, contains about 30 per cent. of chlorine, but if old not more than 10 per cent. Bleaching powder is employed in bleaching and as a disinfectant; acids decompose it and liberate the chlorine.

MAGNESIUM.

320. MAGNESIUM, Symb. Mg ; Equiv. 12; Spec. Grav. 1.7; was discovered in the year 1809 by Bussy, in *magnesia*, which was originally brought from Magnesia in Asia Minor. Magnesium is a silvery white brilliant metal; is hard, and malleable; is fusible at a red heat; is slowly oxidized by water; and burns with a brilliant white light when heated in O , Cl , Br , I , or S vapor.

321. MAGNESIA, Symb. MgO , is obtained by roasting the carbonate ; it has a spec. grav. of 3.810 ; forms a protohydrate with water ; is nearly insoluble, 1 part of MgO requiring 55,500 parts of water to dissolve it : when present in lime, it greatly modifies the nature of the lime, preventing the quicklime from becoming mild, and thus rendering it unfit for agricultural purposes ; when pure, it is called *calcined magnesia*, or *magnesia usta*.

322. The principal compounds of magnesia are the following :—

Carbonate of magnesia (neutral), ... MgO, CO_2

Magnesia Alba, $3(MgO, CO_2) + MgO, HO + 3HO$.

Sulphate of magnesia (Epsom Salts), $MgO, SO_3, 7HO$.

Beside these, there are various silicates of magnesia, as Steatite or soap-stone, Meerschaum, Chrysolite, Serpentine, &c. Augite and Tremolite are essentially double silicates of magnesia and lime. Dolomite or Magnesian Limestone is a double carbonate of magnesia and lime = $(MgO, CO_2 + CaO, CO_2)$.

323. SULPHATE OF MAGNESIA or Epsom salts, occurs native as an efflorescence in some parts of Spain ; is found in certain springs of water, as those of Epsom and Cheltenham in England, and Seidlitz and Pullna in Bohemia ; is prepared from bittern or mother liquor of salt by evaporation and crystallization, the rough crystal being called single Epsom salts, and those obtained by a recrystallization double Epsom salts ; is also obtained by saturating dilute sulphuric acid with magnesian limestone, and upon the precipitation of the sulphate of lime, evaporating the clear solution and crystallizing the sulphate of magnesia. Epsom salts crystallizes in fine needle-like rectangular prisms with 6 equivalents of water, but the amount of water and the form of the crystals depend to some extent upon the temperature of crystallization. The salt is very soluble in water, 100 parts of cold water taking up 68, and of hot water 150 parts of the salt.

BARIUM.

324. BARIUM, Symb. Ba ; Equiv. 69 ; Spec. Grav. 4.000; was discovered by Davy in 1808, named from *barus* "heavy" on account of the great density of its compounds, occurs in considerable abun-

dance combined with oxygen or with acids. Barium is a white, malleable, rather lustrous metal; fuses at a red heat, and at a higher temperature volatilizes; slowly oxidizes in air, and at a high temperature burns; decomposes water with energy at ordinary temperatures.

325. The principal compounds of barium are:

Baryta or protoxide of barium.....	<i>BaO,</i>
Chloride of barium.....	<i>BaCl.</i>

326. BARYTA is prepared by heating the nitrate of baryta to bright redness until no more fumes are given off. It is a very heavy gray porous mass, which absorbs water on exposure to the air, and falls to a white powder of hydrate of baryta. The hydrate fuses at dull redness, and becomes crystalline on cooling; it is soluble in 2 parts of boiling or in 20 parts of cold water, and by continued exposure to the air passes into carbonate of baryta. The hydrate of baryta and all its soluble salts are eminently poisonous.

327. The chief salts of baryta are:

Nitrate of baryta.....	<i>BaO₂NO₃</i>
Sulphate of baryta.....	<i>BaO₂SO₄</i>
Carbonate of baryta.....	<i>BaO₂CO₃</i>

NOTE. The chloride of barium and nitrate of baryta are much used as tests for sulphuric acid with which they form insoluble sulphate of baryta. The carbonate is known as the mineral *Witherite*; the sulphate as *Cavcav* or *Heavy-spar*.

STRONTIUM.

328. STRONTIUM, Symb. *Sr*; Equiv. 44; was discovered by Davy in 1808. It is a white metal, heavier than oil of vitriol—in which it sinks; was named from Strontian in Scotland, where it was discovered. Its salts and other compounds bear a very close resemblance to the corresponding compounds of barium, and are distinguished by the red tinge they impart to flame.

METALS OF THE EARTHS PROPER.

LECTURE XX.

ALUMINUM.

329. ALUMINUM, Symb. *Al*; Equiv. 13.7; Spec. Grav. 2.500; was discovered in the year 1808, by Davy, in clay, and was named from *alumen*, the Latin name of alum.

Aluminum is an iron-grey solid, having but little metallic lustre; is almost infusible; is combustible; is not acted upon by water; is hard and very sonorous; is rather malleable and ductile; forms alloys with copper, silver, and iron, but not with lead or mercury; its alloy with copper is very hard, and takes a high degree of polish.

330. ALUMINA OR SESQUIOXIDE OF ALUMINUM, Al_2O_3 , exists native, almost pure, in the Sapphire, Ruby, Topaz, Corundum, &c. (Emery is an impure corundum.) It is obtained by adding ammonia to a solution of alum; it is a white, tasteless solid, insoluble in water, and without action or colored tests; is highly hygrometric; when moist and freshly precipitated, it is remarkably plastic, and hence its use in pottery, &c.; it has a strong affinity for organic fibre, and also for coloring matter, and is therefore used in dyeing as a mordant (French *mordant*, "biting"). The pigments called *lakes* are made by precipitating solutions of coloring matter by alumina; is a most powerful absorber of ammoniacal salts, and hence one reason of its great value as a manure.

331. The principal compounds of alumina are the alums and the silicates. An alum is a double-salt composed of sulphate of a protoxide combined with the neutral sulphate of a sesquioxide, and crystallized in cubes or octahedra with 24 equivalents of water, its general formula being:



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332. The principal alums and their formulæ are :

Potash-alum.....	$K_2SO_4 + Al_2O_3 \cdot 3SO_3 + 2HO.$
Soda-alum.....	$Na_2SO_4 + Al_2O_3 \cdot 3SO_3 + 4HO.$
Ammonia-alum.....	$NH_4O, SO_3 + Al_2O_3 \cdot 3SO_3 + 24HO.$
Potash-iron-alum.....	$K_2O, SO_3 + Fe_2O_3 \cdot 3SO_3 + HO.$
Soda-manganese-alum.....	$Na_2O, SO_3 + Mn_2O_3 \cdot 3SO_3 + 24HO.$
Ammonia-chrome-alum.....	$NH_4O, SO_3 + Cr_2O_3 \cdot 3SO_3 + 24HO.$

333. The SILICATES OF ALUMINA are very numerous and constitute a large portion of the solid crust of the earth. The principal are the following :

Potash Feldspar $KO, SiO_3 + Al_2O_3 \cdot 3SiO.$

Soda Feldspar called albite.

Lithia Feldspar.

Lime Feldspar.

Mica is a double silicate of Al_2O_3 and SiO_2 , the latter being often replaced by CaO , or Fe_2O_3 .

Hornblende is a common silicate of Al_2O_3 with lime, magnesia and oxide of iron.

Granite and gneiss are compounds of Quartz, feldspar and Mica.

Clays are hydrated silicates of alumina, the purest, being kaolin $Al_2O_3 \cdot SiO_3 + 3HO$. This particular variety is employed in the manufacture of porcelain and is produced by the disintegration of feldspathic rock. Potter's clay contains iron, and hence its red color.

Ochres are clays colored by iron.

Umber and sienna are clays colored by iron and manganese.

Fuller's earth is a peculiarly absorbent clay.

Many varieties of slates are nearly pure clays.

Emerald or Beryl is a double silicate of alumina and glucina.

OTHER METALS OF CLASS III.

334. GLUCINUM, YTTRIUM, THORIUM, ZIRCONIUM, ERBIUM AND TERBIUM are the other metals belonging to the class of metallic bases of the earths proper. They are found only in small quantities, and for the most part only in very rare minerals. In general appearance and properties their oxides closely resemble alumina.



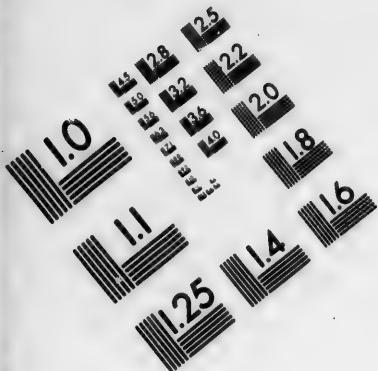
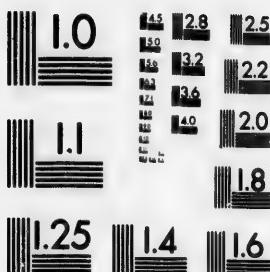
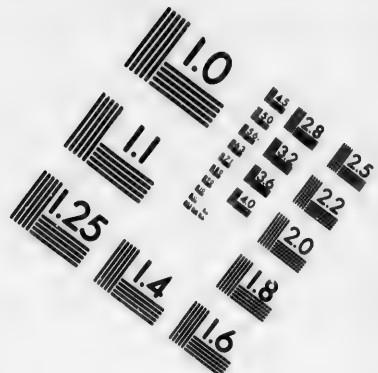
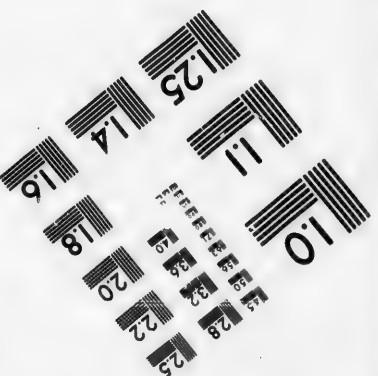
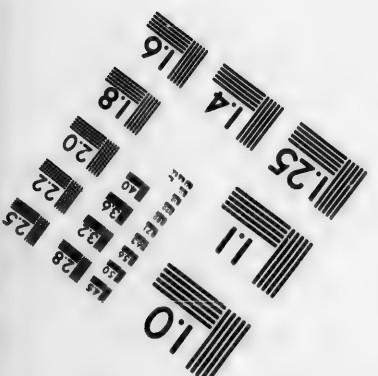


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METALS PROPER, OF WHICH THE PROTOXIDES ARE ISOMURPHOUS WITH MAGNESIA.

ZINC.

335. Zinc, Symb. Zn ; Equiv. 32.5; is a bluish white, lustrous, lamellar, crystalline metal, brittle at ordinary temperatures, malleable at $212^{\circ} F.$, and brittle again at $400^{\circ} F.$; fuses at a red heat, and boils at a white heat; all of its salts are poisonous.

336. The compounds of zinc are chiefly the oxide ZnO , and the chloride $ZnCl_2$, and the principal salts of the oxide are:

Carbonate of zinc, *zinc bloom, calumine,..* $2(ZnO, CO_2) + 3(H_2O)$.

Sulphate of zinc, *white vitriol,.....* $ZnO, SO_3, + 7H_2O$.

NOTE. The oxide of zinc is employed as a white paint in place of white lead, as it possesses the advantage of not being dangerous to the workmen, and of not being blackened by sulphuretted hydrogen. Sulphate of zinc is employed by dyers, and is used as an emetic, but is poisonous in large doses.

NICKEL.

337. NICKEL, Symb. Ni ; Equiv. 29.5; is found rather abundantly in nature; often associated with iron or arsenic; is a greyish white lustrous malleable and ductile metal; is attracted by the magnet; is about as fusible as iron, and, like iron, decomposes water at a red heat.

338. The principal oxide of nickel is the protoxide, and its other chief compounds are the chloride $NiCl_2$, and the proto-sulphide NiS . The protoxide combines with nitric acid to form nitrate of nickel $NiO, NO_3, + 6H_2O$, and with sulphuric acid to form sulphate of nickel $NiO, SO_3, + 7H_2O$. These and most other salts of nickel are of a fine green color, and are poisonous.

COBALT.

339. COBALT, Symb. Co ; Equiv. 29.5; is about as abundant as nickel, and bears a very marked resemblance to that metal in nearly all its properties. Its name is derived from the Kobolds, or evil spirits of the mine, and was given to it by the ignorant German miners of the middle ages, who were frequently deceived by

the fine appearance of its ores, which were nevertheless valueless until the close of the 16th century, when they were first employed for coloring glass. Cobalt is attracted by the magnet. There are several oxides of cobalt; the protoxide is basic, and combines with acids to form salts, which are red when hydrated, but blue when the water of hydration is expelled. The soluble salts are poisonous.

CADMIUM.

340. CADMIUM is found in nature chiefly associated with zinc, but not in large quantities. In its physical properties it resembles tin. It has one oxide, viz: the protoxide; but neither the oxide, nor its salts, nor the metal itself is of any practical importance in the arts.

LECTURE XXI.

COPPER.

341. COPPER, Symb. Cu. (cuprum); Equiv. 32; is a red lustrous metal, very malleable and ductile, ranking in the former respect next after gold and silver, and in the latter next after platinum, gold, silver and iron; in tenacity comes next to iron; is the most sonorous of metals; its spec. grav. varies from 8.78 to 8.96; fuses at a red heat, and is somewhat volatile at a white heat, its vapor burning with a bright green flame; is precipitated from its solution in small cubical crystals; oxidizes in moist air or in contact with acids on fatty matters. The salts of its protoxide are all exceedingly poisonous.

342. The principal compounds of copper are:

Suboxide of copper, red oxide of copper, cuprous oxide,..	Cu_2O
Protoxide of copper, black oxide, cupric oxide,.....	CuO
Binoxide of copper,.....	CuO_2
Sub-chloride of copper,.....	Cu_2Cl
Chloride of copper,.....	$CuCl$
Sub-sulphide of copper,.....	Cu_2S
Sulphide of copper,.....	CuS
Copper pyrites.....	Fe_2S_3, Cu_2S

343. THE SUBOXIDE OR DINOXIDE OF COPPER may be prepared by adding a solution of sugar to a solution of sulphate of

copper, and adding potassa until the precipitate first produced is re-dissolved to a violet blue fluid, the red oxide of copper is precipitated upon boiling this for some time. Cu_2O is not altered by exposure to air; is resolved by acids into metallic copper, and the protoxide, with the latter of which the acid combines; is a feeble base but its salts possess little practical interest; imparts a fine red color to fluxes and is hence used for coloring glass; the surface of vessels of polished copper is often bronzed by conversion into red oxide to enable it to resist the action of air and moisture; this is commonly accomplished by exposing them to the action of a boiling solution of acetate of copper.

344. THE PROTOXIDE OR BLACK OXIDE OF COPPER is a very hygroscopic black powder: is obtained by igniting nitrate of copper; is reduced with extreme facility by carbon or hydrogen at a low red heat; is a very powerful base—combining with acids to form the so-called *cupric salts*; is employed to give a blue or green color to glass. Cupric salts have an acid reaction, and are in color either blue or green; they are very poisonous, but their effect upon the animal economy is, in a measure, counteracted by grape sugar, which to some extent reduces the cupric salt to insoluble and inert suboxide of copper; the proper antidote for cupric salts is however an excess of albumen which forms with them insoluble albuminates of copper.

345. The principal cupric and cuprous salts are the following:

Nitrate of copper or cupric nitrate,.....	$CuO, NO_3 + 3HO.$
Sulphate of copper or cupric sulphate,.....	$CuO, SO_3 + 5HO.$
Neutral acetate of copper, <i>distilled verdigris</i> ,....	$CuO, (C_4H_3O_3) + HO.$
Sub-acetate of copper, <i>common verdigris</i> ,.....	$(CuO)_2, (C_4H_3O_3) + 6HO$
Sub-carbonate of copper, <i>mineral green</i> ,.....	$(CuO)_2, CO_2.$
Native green carbonate of copper, <i>malachite</i> ,....	$CuO, CO_2 + CuO_2 + HO.$
Schweinfurt green, double acetate and arsenite of copper,.....	$CuO, (C_4H_3O_3) + 3(CuO, AsO_3).$

346. NITRATE OF COPPER is obtained by acting on copper with moderately strong nitric acid, and crystallizing. The salt crystallizes in dark blue prisms which deliquesce in air, and are very soluble in water; oxidizes many metals with considerable energy.

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$-5HO$.

$(CuO_3)+HO$.

$(H_3O_3)+6HO$

J_2 .

CuO_2+HO .

(CuO, AsO_3) .

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347. SULPHATE OF COPPER, *blue vitriol, blue stone, blue copperas*, may be formed by dissolving copper in sulphuric acid diluted with half its bulk of water, and then crystallizing ; the crystals are fine transparent blue oblique rhombic prisms which dissolve in 4 parts cold or 2 parts boiling water, but are insoluble in alcohol. Sulphate of copper is used in galvano-plastic as a source of copper, and in medicine as an emetic and an escharotic ; is also employed in dyeing ; is very poisonous.

LECTURE XXII.

MANGANESE.

348. MANGANESE, Symb. Mn ; Equiv. 27.5 ; Spec. Grav. about 7.000 ; was discovered by Gahn, in the year 1775, in an ore previously examined by Scheele, and called manganese (also *magnesia nigra*) ; is a greyish white, brittle metal, very oxidizable, and is best preserved in naphtha.

349. The compounds of manganese and oxygen are five in number, with two compound oxides. They are as follows :—

Protioxide or manganoxide,.....	MnO .
Sesquioxide or manganic oxide,.....	Mn_2O_3 .
Binoxide or peroxide,.....	MnO_2 .
Manganoso oxide or red oxide,.....	Mn_3O_4 or $MnO+Mn_2O_3$.
Varvicide,.....	Mn_4O_7 or $Mn_2O_3+2MnO_2$.
Manganic acid,.....	MnO_3 .
Permanganic acid,.....	Mn_2O_7 .

NOTE.—The acids, manganic and permanganic, are known only in combination with bases.

I R O N.

350. IRON (Lat. *Ferrum*), symb. Fe ; equiv. 28 ; spec. grav. 7.700 ; was known in very ancient times ; has a bluish-grey color, and a strong metallic lustre ; is very ductile, moderately malleable, and exceedingly tenacious. Its melting-point is very high (2786°) ; it becomes pasty before it melts, and is then capable of being *welded*, and also of being hammered or moulded into any form ; is magnetic, and in the form of steel may be made permanently so, but the magnetism of soft iron is very transient ;

oxidizes very slowly in dry air at ordinary temperatures, but rapidly in moist air or when heated; burns in the air at a white heat, or in oxygen, in which it throws off brilliant scintillations.

351. The principal compounds of iron are the following :

Protoxide of iron,.....	FeO .	Perchloride of iron,.....	Fe_2Cl_9 .
Sesquiox. or perox. of iron,..	Fe_2O_3 .	Protoiodide of iron,.....	FeI .
Black oxide of iron,....	Fe_3O_4 .	Protosulphide of iron,.....	FeS .
Ferric acid,.....	FeO_3 .	Sesquisulphide of iron,....	Fe_2S_3 .
Protochloride of iron,.....	$FeCl$.	Bisulphide of iron,.....	FeS_2 .

352. PROTOXIDE OR FERROUS OXIDE OF IRON, FeO , is a very powerful base; is almost unknown in a separate state, owing to its tendency to attract an additional quantity of oxygen and become peroxide; it combines with acids to produce salts, which have generally a pale green color, though some are colorless.

353. SESQUIOXIDE OF IRON, PEROXIDE OF IRON OR FERRIC OXIDE, Fe_2O_3 , is a feeble base; is isomorphous with alumina; is not magnetic; with acids it forms salts, which are in color either yellow, brown, or red.

354. BLACK OXIDE OF IRON, MAGNETIC OXIDE; LOADSTONE; Fe_3O_4 ; is regarded as a mixture of protoxide and sesquioxide, i. e. $Fe_3O_4 = FeO + Fe_2O_3$. It is incapable of forming salts.

355. FERRIC ACID, FeO_3 , corresponds to manganic acid, and, like it, has never been isolated. It forms salts called *ferrates*.

356. PROTOSULPHIDE OF IRON is much used as a source of sulphuretted hydrogen: the bisulphide occurs native crystallized in cubes, under the name of *iron pyrites*, and is sometimes used as a source of sulphur.

357. The principal salts of the protoxide of iron are :—

CARBONATE OF IRON, OR CARBONATE OF THE PROTOXIDE OF IRON, FeO , CO_2 , which occurs native in chalybeate waters, and also in spathozo iron-ore and clay iron-stone.

PROTOSULPHATE OF IRON; SULPHATE OF THE PROTOXIDE OF IRON; FERROUS SULPHATE; GREEN VITRIOL OR COPPERAS, FeO_3SO_4 , $HO+6HO$.

**PROTONITRATE OF IRON; NITRATE OF THE PROTOXIDE OF IRON,
FERROUS NITRATE, FeO, NO_3 .**

358. The principal salts of the peroxide of iron are :

PERSULPHATE OF IRON, SULPHATE OF THE PEROXIDE, FERRIC SULPHATE, $Fe_2O_3, 3SO_3$.

FERRIC OXALATE, $Fe_2O_3, 3C_2O_4$.

FERRIC ACETATE, $Fe_2O_3, 3C_4H_3O_3$.

359. The principal ores of iron are the following :

I. CLAY IRON-STONE—a carbonate of the protoxide, generally containing lime and magnesium.

II. SPATHIC IRON-ORE—crystallized carbonate of protoxide.

III. RED HEMATITE—pure peroxide.

IV. BROWN HEMATITE—hydrated peroxide.

V. SPECULAR IRON-ORE—crystallized anhydrous peroxide.

VI. BLACK OXIDE OR MAGNETIC OXIDE OF IRON.

VII. BLACK BAND—a variety of compact clay iron-stone, containing bituminous matter.

VIII. BOG IRON-ORE—a mixture of hydrated peroxide and phosphate of iron.

IX. IRON PYRITES—a bisulphate of iron, and employed as a source, not of iron but of sulphur.

LECTURE XXIII.

LEAD. At the beginning of 1808

360. LEAD, Symb. Pb ; Equiv. 104 ; is obtained principally from the sulphide (galena) by roasting to expel the sulphur, but there are numerous other ores of the metal. Lead has a spec. grav. of 11.445 ; melts at 612° F., and shrinks considerably upon solidifying ; like most other metals assumes the octahedral form upon crystallizing ; not very easily oxidized when massive, but exposed to the air its surface soon tarnishes by becoming covered by an exceedingly thin film of oxide ; is not affected by pure water free from air at the ordinary temperature, but if air be present the lead is oxidized at its expense, and is hence found in the

water; if carbonic acid or sulphuric acid be present in the water, it combines with the oxide of lead thus formed, and the salt is deposited upon the metal, and being insoluble protects it from further oxidation; hence soft or rain water cannot be safely employed for domestic purposes if preserved in leaden cisterns, but hard water is less contaminated.

361. The principal compounds of lead are the following:

Suboxide of lead,.....	Pb_2O
Protoxide of lead, <i>massicot, litharge,</i>	$Pb O$
Sesquioxide of lead,.....	Pb_2O_3
Binoxide of lead, <i>puce oxide, plumbic acid,</i>	$Pb O_2$
Minium or red lead, <i>plumbate of lead,</i>	$(2PbO+PbO_2)=Pb_3O_4$
Chloride of lead,.....	$Pb Cl$
Sulphide of lead or <i>galena,</i>	PbS
Oxy-chloride of lead, <i>mineral, Paris or Turner's yellow,</i>	$PbCl_7PbO.$

362. The only oxide of lead that is salifiable is the protoxide; this is called massicot when it has not been fused, and litharge when crystallized by fusion.

PbO is soluble in 7000 parts of distilled water, but is much more soluble in water containing sugar. All of its salts are poisonous, but none eminently so. The sub-acetate is a more powerful poison than the carbonate. The sulphate of lead is insoluble, and hence sulphuric acid and soluble sulphates are employed as antidotes for lead. A compound of litharge and lime is used for dyeing the hair of a purplish black color, the change of color being due to the action of the sulphur of the hair, which, with the lead, produces black sulphide of lead.

363. The principal salts of the protoxide of lead are the following:

Nitrate of lead,.....	$PbO,NO_5.$
Sulphate of lead,.....	$PbO,SO_3.$
Carbonate of lead, <i>ceruse, white lead,</i>	$PbO,CO_2.$
Chromate of lead, <i>chrome yellow,</i>	$PbO,CrO_3.$

364. CARBONATE OF LEAD is an invaluable pigment, is insoluble in pure water, but dissolves in water containing carbonic acid or any other acid which forms a soluble compound with its base; is blackened by sulphuretted hydrogen, hence the blackening

of common white paints in stables and other places where that gas is evolved ; is also employed in glazing cards.

METALS PROPER ALSO HAVING ISOMORPHOUS RELATIONS WITH THE MAGNESIAN FAMILY.

365. The only metals of much practical interest or importance belonging to this class are tin, and chromium. Of the others, vanadium and tellurium are among the rarest of the elements.

TIN.

366. *Tin*, Symb. *Sn*, (Stannum) ; Equiv. 59 ; is a white metal with a faint tinge of yellow, one of the softest, and most malleable of the metals ; possesses but little elasticity and tenacity ; has a great tendency to crystallize, the crackling noise heard when a bar of tin is bent is due to the friction of the crystals upon one another ; melts at 442° F., and when poured into a hot iron mortar and continually stirred till cold it may be reduced to powder ; is but slightly volatile even at a white heat ; but burns in the air at a very elevated temperature, being converted into binoxide ; is not altered by exposure to the air at ordinary temperatures.

367. The principal compounds of tin are the following :

Protoxide of tin, <i>stannous acid</i>,	.....	<i>Sn O</i>
Binoxide of tin, <i>stannic acid</i>,	.....	<i>Sn O₂</i>
Metastannic acid,	.....	<i>Sn₅ O₁₀</i>
Protochloride of tin,	.....	<i>Sn Cl</i>
Perchloride or bichloride of tin,	.....	<i>Sn Cl₂</i>
Sulphide of tin,	.....	<i>Sn S</i>
Bisulphide, <i>aurum musivum</i> , <i>mosaic gold</i> or <i>bronze powder</i>,	.....	<i>Sn S₂</i>

368. **PROTOXIDE OF TIN** is obtained from protochloride of tin by precipitation with an alkaline carbonate. Thus obtained it is a white hydrate, which heated to redness in an atmosphere of carbonic acid, becomes black anhydrous oxide ; is also known in the form of olive-green and red powders. When heated in air the protoxide burns like tinder, and becomes binoxide. *SnO* is insoluble in water but is soluble in acids ; with which it combines to form salts which are not very well-known. **STANNIC**

ACID, SnO_3 , is obtained by precipitating the bichloride of tin, and is sometimes employed in polishing, under the name of *putty powder*. PROTOCHLORIDE OF TIN is obtained by boiling fragments of tin in dilute hydrochloric acid and evaporating to crystallization. BICHLORIDE OF TIN may be obtained by saturating a strong solution of protochloride of tin by means of a current of chlorine gas. Both of the chlorides may also be obtained in an anhydrous state; they are chiefly of use as re-agents and in the process of dyeing. BISULPHIDE OF TIN is prepared in the dry way by igniting a mixture of stannic oxide, sulphur, and sal-ammoniac in a covered crucible.

CHROMIUM.

369. CHROMIUM, Symb. Cr , Equiv. 27, exists rather abundantly in nature as chrome-iron and as chromate of lead; exists to the extent of about 6 per cent. in the ruby; also gives color to the emerald.* Chromium is magnetic only at very low temperatures; is very infusible; is attacked with difficulty by acids; has a spec. grav of about 5.9.

370. The principal compounds of chromium are:

Protoxide of chromium or chromous oxide,.....	CrO
Sesquioxide of chromium or chromic oxide,.....	Cr_2O_3
Chromic acid,.....	CrO_3

371. The principal salts of chromium are those of the sesquioxide and the chromic acid, and of these the chief are:

SULPHATE OF SESQUIOXIDE OR CHROMIC SULPHATE, $\text{Cr}_2\text{O}_3 \cdot 3\text{SO}_4$ exists in three forms, viz: the violet and green salts, each containing 15 equiv. of water of crystallization, and the red salt which is anhydrous.

CHROMATE OF POTASSA, $\text{KO} \cdot \text{CrO}_3$, exists as bright yellow anhydrous crystals, soluble in water, but not in alcohol; poisonous.

BICHROMATE OF POTASSA, $\text{KO} \cdot 2\text{CrO}_3$, exists in bright red tubular crystals.

CHROMATE OF SODA, $\text{NaO} \cdot \text{CrO}_3 + 10\text{HO}$, exists in hyacinth red six-sided prisms bevelled at the ends.

* It has recently been discovered by M. Tourneau that the colors of gems, smoky quartz, &c., are due, not to metallic oxides, as was formerly supposed, but to volatile hydrocarbons.

CHROMATE OF AMMONIA, NH_4O , CrO_3 , crystallizes in lemon-yellow needles.

CHROMATE OF LEAD, PbO , CrO_3 , is the chrome yellow of painters.

372. The other metals belonging to this class are not likely to fall into the hands of the student, as they are rare and, comparatively speaking, unimportant. They are :

VANADIUM, V , 68·5; a silver white, brittle, nearly infusible metal resembling chromium, and, like it, forming colored compounds. The principal of these are VO , VO_2 , and VO_3 . The last is Vanadic Acid—the second is a basic body. There are likewise several chlorides, sulphides, &c.

MOLYBDENUM, Mo , 46; a white, brittle, infusible metal with a sp. gr. 8·6. Like Vanadium, it forms three oxides, MoO , MoO_2 , and MoO_3 . The last is Molybdic Acid. The Molybdate of Ammonia is employed in analysis for the detection of Phosphoric Acid, and a mixture of Molybdic and Phosphoric Acids for the detection of Ammonia. Mo forms three chlorides and several sulphides.

TUNGSTEN, W (Wolfram), 95, is a white, hard, brittle metal having sp. grav. of 17·6; is chiefly found in the mineral Wolfram; forms two or three oxides, viz. WO_2 , and WO_3 (Tungstic Acid), and an intermediate or blue oxide $W^2O_5 = WO_2 + WO_3$. It also forms several chlorides, sulphides, &c.

TELLURIUM, Te , 64, is a very rare metal resembling silver in appearance; is a poor conductor of heat and electricity, and so nearly resembles the metalloids that it is by some chemists classed with them, and forms a well-marked group with Sulphur and Selenium, which it greatly resembles.* It forms two oxides, Tellurous Acid, TeO_2 , and Telluric Acid, TeO_3 , a compound with hydrogen, TeH , and several chlorides, all of which resemble the corresponding compounds of sulphur.

TITANIUM, Ti , 25, is a rare, copper-red, infusible metal, having a spec. grav. 5·3. Is chiefly found combined with iron in certain parts of the world, especially in the titaniferous iron ores of Canada. It combines with oxygen to form two oxides, TiO and TiO_2 , of which the last is best known and is called Titanic Acid. It also combines with chlorine, nitrogen, &c.

* In several cases elementary bodies may be arranged in groups of three each, so as to form well-marked natural classes. In these cases the second element is intermediate in properties, combining number, &c., between the other two. Thus we have such groups in Chlorine, Bromine, and Iodine; Sulphur, Selenium, and Tellurium; Phosphorus, Arsenic, and Antimony; Potassium, Sodium, and Lithium; Calcium, Strontium, and Barium. For example, we have in the case of the first group named—

Chlorine,	A gas,	Very strong affinities,	Equiv. 35·5.
Iodine,	A solid,	Much weaker affinities,	Equiv. 127.
Bromine,	A liquid,	Intermediate affinities,	Eq. $\frac{127+35\cdot5}{2} = 81\cdot25$

So also the equivalent of Sulphur is 16; of Tellurium it is 64·2, that of Selenium being about $\frac{16+64\cdot2}{2} = 40\cdot1$, &c.

METALS ISOMORPHOUS WITH PHOSPHORUS.

LECTURE XXIV.

BISMUTH.

373. BISMUTH, Symb. *Bi*, Equiv. 213; found abundantly in the metallic state chiefly disseminated in quartz rock; is also found as an oxide, a carbonate and a sulphide: has a greyish white color with a red tinge and a metallic lustre; is very brittle and crystalline; fuses at 480° F., and volatilizes at an incipient white heat; fused bismuth expands in the act of solidifying, and hence its use in type metal; is not acted upon by dry air, but tarnishes if moisture be present; has a specific gravity of 9.654.

374. The principal compounds of bismuth are the following:

Binoxide of bismuth,.....	<i>Bi O₂</i>
Teroxide of bismuth,.....	<i>Bi O₃</i>
Quadroxide of bismuth,.....	<i>Bi O₄</i>
Pentoxide of bismuth, <i>bismuthic acid</i> ,.....	<i>Bi O₅</i>
Terchloride of bismuth,.....	<i>Bi C₃</i>
Bisulphide of bismuth,.....	<i>Bi S₂</i>
Tersulphide of bismuth,.....	<i>Bi S₃</i>

375. THE TEROXIDE OF BISMUTH (sometimes spoken of as protoxide or sesquioxide) forms a class of salts which are very heavy, white, poisonous, and which exert an acid reaction; they are nearly all decomposed by water which throws down an almost insoluble basic salt, the acid remaining in solution. The most important of its salts is the nitrate. Of this there are two or three varieties, as the neutral nitrate $Bi O_3 3NO_5 + HO$, and the basic nitrate $BiO_3 NO_5 + HO$. The latter is known as *bismuthum album* or *flake white*. The terchloride of bismuth is used as a cosmetic under the name of *pearl white*.

ANTIMONY.

376. ANTIMONY, Symb. *Sb (Stibium)*, Equiv. 129; is obtained from the native sulphide; the metallic antimony of commerce is always more or less impure, and is capable of being purified only

with great difficulty ; is a white brilliant metal of a lamellated structure and density of about 6.75 ; is not acted upon by exposure to the air ; fuses about 800° F. and volatilizes at a white heat ; is not, however, sufficiently volatile to be distilled ; burns in the air at a red heat producing abundant fumes of oxide of antimony.

377. The principal compounds of antimony are :

Teroxide of antimony, <i>antimonous acid</i> ,.....	<i>Sb O₃</i>
Pentoxide of antimony, <i>antimonic acid</i> ,.....	<i>Sb O₅</i>
Antimonuretted hydrogen,.....	<i>Sb H₃</i>
Terchloride of antimony, <i>butter of antimony</i> ,.....	<i>Sb Cl₃</i>
Oxychloride of antimony, <i>powder of Algaroth</i> , .. <i>Sb Cl₃</i> + 2 <i>Sb O₃</i> + <i>HO</i>	
Pentachloride of antimony,.....	<i>Sb Cl₅</i>
Tersulphide of antimony,.....	<i>Sb S₃</i>
Pentasulphide of antimony, <i>golden sulphide of antimony</i> ,.....	<i>Sb S₅</i>

378. TEROXIDE OF ANTIMONY may be prepared by dissolving the prepared sulphide in about four times its weight of *HCl*, thus



the dissolved terchloride is then precipitated as teroxide by adding an excess of carbonate of potassa, and boiling. It is a white insoluble body, which crystallizes in needles, fuses at a red heat, and at a higher temperature volatilizes ; combines with acids to form salts, which, when soluble, have an acid reaction. ANTIMONIC ACID, *Sb O₅*, is produced by the action of strong nitric acid on the teroxide of antimony ; it is, when thus prepared, a hydrated solid *Sb O₅* + 5 *HO*, slightly soluble in water, and less so in dilute mineral acids ; it combines with bases to form a class of neutral salts, the general formula of which is *MO*, *Sb O₅*. Most of the salts of antimony are decomposed by water.

NOTE.—Terchloride of antimony or *butter of antimony* may be obtained in several ways—as by passing chlorine over antimony, by dissolving *Sb S₃* in *H Cl*, &c. It is a soft grey solid ; a powerful cautery ; is decomposed by excess of water, forming *powder of Algaroth*.

The tersulphide is the common ore of antimony, and is obtained as a fine orange red precipitate when *HS* is passed through a solution of *Sb O₃*, or one of its salts. *Kermes mineral* is a mixture of *Sb S₃* with *Sb O₃* and *Sb S₅* and an alkaline sulphide,—it is obtained by dissolving the prepared sulphide in a solution of caustic potash, and then adding an acid.

379. The principal salts of antimony are the following :

Antimonate of antimony,.....	$Sb O_3, Sb O_5 = 2 (Sb O_4)$
Antimonate of potash,.....	$K O, Sb O_5, + 5HO$
Antimonate of lead, <i>Naples yellow</i> ,.....	$PbO, Sb O_5$
Oxalate of potash and antimony,.....	$K O, C_2 O_3 + Sb O_3, 3 C_2 O_3$
Tartrate of potash and antimony,.....	$K O, Sb, O_3 + C_8 H_4 O_{10} + 2 HO$

NOTE.—The last two salts differ from the ordinary compounds of antimony in not being decomposed by water, the tartrate of potash and antimony, or *tartar emetic*. *Potash tartrate of antimony* is prepared by neutralizing the bitartrate of potash by means of *teroxide of antimony*. The oxide of antimony is boiled with four times its weight of water and the bitartrate of potash added in small quantities at a time till all the oxide is dissolved. The filtered solution on cooling deposits the crystals of *tartar emetic*,—these crystals become white in the air by losing their water of crystallization. This salt was formerly regarded as a double tartrate of antimony and potash, $K O, C_8 H_4 O_{10} + Sb O_3, C_8 H_4 O_{10}$, but Dumas and Graham and other eminent chemists prefer regarding *tartaric acid* as a dibasic acid having double the atomic weight formerly assigned to it. Upon this view bitartrate of potash is $K O, HO (C_8 H_4 O_{10})$ and substituting one atom of $Sb O_3$ for the atom of water, we get the formula for *tartar emetic* $K O, Sb O_3, (C_8 H_4 O_{10})$.

The acid antimoniate of potash $K O, 2 Sb O_5$, is the *Antimonium diaforeticum lavatum* of the pharmacopœias.

ARSENIC.

380. ARSENIC, Symb. *As*; Equiv. 75; is found in nature usually in combination with sulphur or with other metals as with iron, nickel, cobalt, and copper. The mineral known as *arsenical pyrites* or *mispickel* commonly contains iron, sulphur, and arsenic, in the proportions represented by $Fe S_2 + Fe As_2$. Metallic arsenic may be obtained from the sulphide, or by reducing a mixture of one part of arsenious acid and three parts of black flur, and condensing the volatilized metal. Arsenic is a steel-grey lustrous metal, crystalline and exceedingly brittle; rises in vapor at about $356^{\circ} F.$ without previously melting. The vapor has a strong garlic odor, ascribed by some to the formation of a suboxide, it has a density of 10.39 that of the metal being about 5.75. Arsenic burns in the air with a pale blue flame, producing arsenious acid; exposed to dry air it tarnishes; in moist air it becomes gradually converted into

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arsenious acid. In all of its combinations, as with oxygen, chlorine, hydrogen, &c., arsenic exhibits a very close and remarkable similarity to phosphorus.

NOTE.—Metallic arsenic does not poison until sometime after it has been swallowed—probably not until it has been converted into arsenious acid. The substance sold as *Fly-powder* is a mixture of arsenic with arsenious acid, and is made by exposing the powdered metal to the action of moist air.

381. The principal compounds of arsenic are the following :

Arsenious acid,	<i>As O₃</i>
Arsenic acid,	<i>As O₅</i>
Arseniuretted hydrogen,	<i>As H₃</i>
Bisulphide of arsenic, <i>red orpiment, realgar,</i>	<i>As S₂</i>
Tersulphide of arsenic, <i>yellow orpiment, King's yellow, sulphar-</i> <i>senous acid,</i>	<i>As S₃</i>
Pentasulphide of arsenic, <i>sulpharsenic acid,</i>	<i>As S₅</i>

NOTE.—The pharmaceutical preparations of arsenic are chiefly the arsenical caustic employed in cancer, which is prepared by fusing arsenious acid with tersulphide of arsenic, and the *liquor arsenicalis*, which is a solution of arsenite of potash, and is prepared by dissolving arsenious acid in carbonate of potassa.

382. ARSENIOUS ACID, or WHITE ARSENIC, is obtained as a by-product in roasting certain ores as those of tin, nickel, cobalt, &c., and is purified by resublimation. When freshly prepared, arsenious acid is a transparent massive body, but it rapidly becomes opaque externally, and the opacity gradually travels towards the centre. Newly prepared *As O₃* resembles glass in appearance, while the opaque variety resembles porcelain. The two varieties differ very remarkably in certain respects; thus, the transparent form is at ordinary temperatures about three times more soluble than the opaque, and the specific gravity of the latter is only 3.70, while that of the former is 3.74. Arsenious acid volatilizes without melting at 380° F., producing a colorless, inodorous vapor, of a density of 13.85; *As O₃* is but sparingly soluble in cold water, but more so in hot water; 100 parts of water at 60° take up only about 25 of a part of *As O₃*; the same quantity of water at 212° takes up 11½ parts of the acid, and upon cooling to 60° F. retains 3 parts; it is much more soluble in dilute hydrochloric acid; both it and its soluble salts are

eminently poisonous ; the antidotes to their action are not very reliable ; the best consists in giving a mixture of hydrate of magnesia and ferric sulphate. The iron of the latter forms insoluble arsenate of iron ; and the sulphuric acid combines with the magnesia to form sulphate of magnesia. Other means taken to counteract the effects of the poison are to produce vomiting if it does not occur spontaneously, and to administer oils, or albumen or hydrate of magnesia, which envelope the particles of arsenious acid and protect the coats of the stomach. Arsenious acid is bibasic, and with bases forms salts the general formulæ of which are $2MO, AsO_3$ and MO, HO, AsO_3 .

NOTE.—Arsenious acid enters largely into the composition of bright green paints and colors, as emerald green, Scheele's green, the green colors used in confectionery—the green colors of paper hangings—and hence the unhealthiness of rooms hung with such paper.

383. ARSENIC ACID, AsO_5 , is obtained by heating arsenious acid in considerable excess of nitric and a small quantity of hydrochloric acid ; (8 parts of AsO_3 +24 parts NO_3 +2 parts HCl) evaporating the solution to the consistence of syrup, and then heating pretty strongly to expel the excess of NO_3 and HCl . Arsenic acid is a white deliquescent solid, very soluble in water, but less so after it has been dried ; it is easily reduced to AsO_3 by deoxidizing agents, as sulphurous acid ; is also reduced by a strong heat, but undergoes fusion before reduction. It may be crystallized by slow evaporation from its solution, but it does not retain either its water of crystallization or its basic water with any great degree of force ; it forms poisonous salts, which, like those of phosphorus, are tribasic, having the general formulas $3MO, AsO_5$; $2MO, HO, AsO_5$, and $MO, 2HO, AsO_5$.

384. ARSENIURETTED HYDROGEN, AsH_3 , is prepared by acting on zinc, in presence of AsO_3 , by dilute sulphuric acid. It is a colorless gas having a sickly alliaceous odor ; is very heavy, its specific gravity being 2.695 ; is soluble in water to the extent of 1 vol. in 5, and is completely absorbed by a solution of sulphate of copper or of nitrate of silver ; it burns in the air with a bluish-white flame, being resolved into AsO_3 and H_2O . Arseniuretted hydrogen is exceedingly poisonous when inhaled even in the

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smallest quantities ; this is evident when it is remembered that it contains by weight 98·2 per cent. of arsenic, or that one cubic inch of the gas contains $\frac{1}{3}$ of a grain of arsenic in a finely divided state.

THE NOBLE METALS.

LECTURE XXV.

SILVER.

385. SILVER, Symb. Ag (Argentum), Equiv. 108 ; is a metal of a dazzling white color ; harder than gold, but not so hard as copper ; very malleable and ductile ; is more tenacious than gold but less so than iron, copper and platinum ; it has a spec. grav. of about 10·500 ; fuses at a bright red heat, and at a very bright white heat it volatilises slowly ; is not affected by exposure to air even in the presence of moisture, but becomes covered by sulphide in the presence of air contaminated by HS . Fused silver, under certain circumstances, absorbs mechanically 22 volumes of oxygen from the air, and upon solidifying evolves it again, becoming somewhat arborescent in appearance ; may be obtained pure from silver coin, or standard silver, by dissolving in nitric acid, evaporating nearly to dryness to expel excess of NO_3 , diluting largely with water, and suspending a plate of clean copper, as a clean penny, in the solution of nitrate ; the silver is thus precipitated in a crystalline powder, and must be thoroughly washed by decantation.

386. The chief compounds of silver are :

Suboxide of silver,.....	Ag_2O
Protoxide of silver,.....	AgO
Binoxide of silver,.....	AgO_2
Chloride of silver,.....	$AgCl$
Sulphide of silver,.....	AgS
Iodide of silver,.....	AgI

387. The most important oxide of silver is the protoxide. This is prepared by decomposing nitrate of silver by excess of potassa. It is a dark brown powder, slowly reduced by light, and more rapidly by moderate heat ; a powerful base—uniting with most acids to form (commonly) neutral salts ; dissolves in ammonia to

form fulminating silver, Ag_3N ; colors glass yellow. Its principal salt is the nitrate of silver.

388. NITRATE OF SILVER, *lunar caustic*, Ag O, NO_5 , is best prepared by obtaining the pure metal as directed in Art. 385, and dissolving it in dilute nitric acid with aid of heat. Upon evaporation it crystallizes in colorless square tables which are anhydrous; soluble in 1 part cold or in $\frac{1}{4}$ part of boiling water, or in 4 parts boiling alcohol; fuses at 426° F. , and is cast into little sticks for surgeons, who use it as a cautery; is a very valuable reagent; blackens in contact with organic matter upon exposure to light, and is hence used in photography, and in the manufacture of the so called indelible inks:—the best permanent marking ink consists of 1 part Ag O, NO_5 , and 4 parts of gum arabic dissolved in 4 parts of water. The linen previous to marking should be wetted with a solution of carbonate of soda.

GOLD.

389. GOLD, Symb. Au (*Aurum*), Equiv. 98.5*; spec. grav. 19.300; is the only metal of a yellow color; most malleable of all metals; also very ductile, but not so tenacious as many; is almost as soft as lead; fuses at about 2500° F. , and contracts considerably in becoming solid; is not volatilized in the most intense heat of a furnace, but slowly passes into vapor between the electrodes of a powerful battery, in the oxy-hydrogen flame, or in the focus of a powerful burning glass; does not tarnish in the air at any temperature, nor in presence of moisture; is not acted upon by any single acid; is dissolved in a mixture of nitric and hydrochloric acids; is capable of being welded at high temperatures.

390. The principal compounds of gold are the following:

Suboxide of gold, <i>aurous oxide</i> ,.....	Au_2O
Sesquioxide of gold, <i>auric oxide</i> , <i>auric acid</i> ,.....	Au_2O_3
Subchloride of gold, <i>aurous chloride</i> ,.....	Au_2Cl
Sesquichloride of gold, <i>auric chloride</i> , <i>perchloride</i> ,.....	Au_2Cl_3
Subsulphide of gold, <i>aurous sulphide</i> ,.....	Au_2S
Sesquisulphide of gold, <i>auric sulphide</i> ,.....	Au_2S_3

* Some chemists double the above number for the equiv. of gold, making it 197. In this case the oxides are Au O and Au O_3 , the chlorides Au Cl and Au Cl_3 , &c.

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391. Neither of the oxides of gold is capable of combining with oxygen acids, but the auric oxide combines energetically with bases to form salts which are generally colorless, and which for the most part are not decomposed by water. The principal salts of gold are:

Aurate of ammonia, <i>fulminating gold</i> ,	$2NH_3$, $Au_2O_3 + HO$
Aurate of potash,	KO , $Au_2O_3 + 6HO$
Auro-sulphite of potash,	KO , $Au_2O_3 + 4(KO, 2SO_2) + 5HO$
Purple of Cassius,	$Au_2O, SnO_2 + SnO, SnO_2 + 4HO$

392. THE SESQUI-CHLORIDE OF GOLD, Au_2Cl_3 , is obtained by dissolving gold in 1 part nitric acid and 4 parts hydrochloric acid, and carefully evaporating the solution on a water bath. Thus procured, it is a deliquescent dark-red crystalline mass, which is readily decomposed, leaving sub-chloride of gold or metallic gold according to the temperature. It is soluble in water, alcohol, and ether, and its solution has an acid reaction and a yellow color. Ether removes it from solution in water, and the ethereal solution is sometimes used medicinally under the name of *aurum potabile*. The sesquichloride or perchloride is very easily decomposed and reduced, as by H , C , CO , NO_2 , P , SO_2 , PO_3 , PO_5 and its salts, nearly all the metals, and most organic substances. It combines with most other chlorides to form double salts.

PLATINUM.

393. PLATINUM, Symb. Pt , Equiv. 98.5, spec. grav. 21.53, exists in three forms, viz. metallic platinum, black platinum, and spongy platinum; platinum-black is prepared by dissolving protochloride of potassium in a concentrated solution of potash by aid of heat, and adding alcohol by small quantities at a time, with constant stirring, the precipitated platinum-black must be purified by boiling successively in alcohol, hydrochloride acid and potash, and finally four or five times in water. Spongy platinum is prepared by heating to redness the double chloride of ammonium and platinum. Metallic platinum is a nearly white metal, very lustrous, very malleable, ductile and tenacious; rather harder than copper, but softer than silver;

is not effected by exposure to air at any temperature, and is not melted even in the hottest furnaces ; may however be fused in the flame of the oxy-hydrogen blowpipe, or between the electrodes of a powerful battery ; is easily welded at high temperatures ; is insoluble in all acids except aqua-regia.

394. The principal compounds of platinum are :

Protoxide of platinum, <i>platinous oxide</i> ,.....	<i>Pt O</i>
Binoxide of platinum, <i>platinic oxide</i> ,.....	<i>Pt O₂</i>
Protochloride of platinum,.....	<i>Pt Cl</i>
Bichloride of platinum,.....	<i>PtCl₂</i>
Protosulphide of platinum,.....	<i>Pt S</i>
Bisulphide of platinum,.....	<i>Pt S₂</i>

395. THE BICHLORIDE OF PLATINUM, which is of great use in analysis, is prepared by dissolving the metal in one part nitric acid, and two parts hydrochloric, evaporating to the consistence of a syrup, re-dissolving in hydrochloric acid and again evaporating to expel the nitric acid. The syrupy residue solidifies, on cooling, into a dark red non-crystalline, deliquescent mass, which is soluble in water and in alcohol. When heated it is converted into protochloride or into metallic platinum, according to the temperature. The solution of bichloride of platinum is yellow, but if any iridium or protochloride of platinum be present, the solution is red.

LECTURE XXVI.

MERCURY.

396. MERCURY, Symb. *Hg* (*Hydrargyrum*), Equiv. 100 ; spec. grav. 13.596—also called Quicksilver (i. e., moving silver)—is the only metal that is fluid at ordinary temperatures ; solidifies at—40° F., and boils at about 662° F., yielding a transparent vapor ; volatilizes slowly at all temperatures above 68° F. The mercury of commerce is generally very pure, but it is sometimes contaminated with other metals, as tin, lead, &c., and then has its fluidity remarkably impaired ; may be purified by distilling from half its weight of iron filings, or by digesting it with dilute nitric acid* or solution of corrosive sublimate, either

*It should be agitated in a porcelain dish with a mixture of 1 part nitric acid and 2 parts water, the dish and its contents being kept heated to 180° F.

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of which separates from it the metals more oxidizable than itself. Have no certain means of determining whether the equivalent of mercury is 100 or 200, as we are in ignorance of any isomorphous relations of Hg with the magnesian metals ; but the higher oxide is the more stable, as also are its salts,—a strong argument in favor of its being the protoxide, and indeed it is very generally now so considered. Hg never dissolves in hydrated acids by substitution for hydrogen ; is not affected by hydrochloric or by dilute sulphuric acid, but is rapidly oxidized and dissolved by nitric acid.

397. The principal compounds of mercury are :

MERCUROUS OXIDE, <i>suboxide, black oxide,</i>	Hg ₂ O
MERCURIC OXIDE, <i>peroxide, red oxide,</i>	HgO
MERCUROUS CHLORIDE, <i>subchloride, calomel,</i>	Hg ₂ Cl
MERCURIC CHLORIDE, <i>protochloride, corrosive sublimate,</i>	HgCl
MERCUROUS SULPHIDE, <i>subsulphide,</i>	Hg ₂ S
MERCURIC SULPHIDE, <i>cinnabar,</i>	HgS
MERCUROUS IODIDE, <i>subiodide,</i>	Hg ₂ I
MERCURIC IODIDE, <i>proto-iodide,</i>	HgI

398. MERCUROUS OXIDE is obtained by acting on calomel with an excess of cold solution of caustic potash ; is a black powder, spec. grav. 10.69 ; is decomposed by light or heat into metallic Hg and protoxide ($Hg_2O = Hg + HgO$) ; unites with acids to form salts, which when soluble are decomposed by water, which combines with a part of their acid and throws down an insoluble subsalt.

399. MERCURIC OXIDE is prepared by several methods, as for example :

I. By heating mercury to near its boiling point by contact with air, when it gradually forms minute crystalline scales of HgO.

II. By heating the nitrate of mercury, HgO, NO_3 , till all the nitric acid is expelled. The mass is calcined almost to redness till it no longer evolves fumes of NO_2 . Thus prepared it forms a brilliant orange red

for several hours. The metal is subsequently to be well washed in water, and dried, first by filtering through blotting-paper, and subsequently by gently heating it.

powder, crystallized in plates, having a density of 11.074, and is called *red precipitate*.

III. By treating solution of corrosive sublimate, $HgCl$, with an excess of caustic potash also in solution. The HgO is thus precipitated as a dense powder of lemon yellow color. This variety appears to have stronger affinities than the common red modification.

Mercuric Oxide is slightly soluble in water, and the solution has an alkaline reaction to delicate color-tests; combines with acids to form salts, many of which when soluble are decomposed by water into an acid salt which remains in solution, and an insoluble salt which is precipitated.

400. MERCUROUS CHLORIDE, or Calomel, may be produced by rubbing up together in a mortar, 4 parts by weight of mercuric chloride, $HgCl$, and 3 parts by weight of mercury, and afterwards subliming the product. It may also be formed by subliming a mixture of 1 equiv. of mercuric sulphate, 1 equiv. metallic mercury, with one third their weight of common salt. The vapor should be collected in hot water, when it condenses into a beautiful white impalpable powder, and the hot water at the same time dissolves out any corrosive sublimate that may be carried over.

Mercurous Chloride may be obtained, in four-sided prisms, by slow and careful sublimation. It is slowly decomposed by the long-continued action of light in metallic mercury and corrosive sublimate ($Hg_2Cl = Hg + HgCl$); is almost insoluble in water, requiring some 250,000 times its weight of water to dissolve it.

401. MERCURIC CHLORIDE, or Corrosive Sublimate, may be obtained by dissolving red oxide of mercury in hydrochloric acid, or by dissolving a mixture of equal parts of mercuric sulphate and common salt. It dissolves in 16 parts cold and 3 parts boiling water, in $2\frac{1}{2}$ parts cold or $1\frac{1}{2}$ parts boiling alcohol, or in 3 parts ether. Its aqueous solution has an acid reaction. $HgCl$ crystallizes from solution in right rhombic prisms; when sublimed, it condenses in colorless octahedra; forms an insoluble compound with albumen, and hence probably its antiseptic

density of power; is not decomposed by H_2SO_4 , HNO_3 , or HCl , but is largely soluble in the last two.

402. THE SUBSULPHIDE OF MERCURY is prepared by precipitating Hg from its solution by means of sulphuretted hydrogen; it is black, and is resolved by heat into metallic mercury and the protosulphide. MERCURIC SULPHIDE may be prepared by fusing one part of sulphur in a crucible and adding by degrees 6 or 7 parts of metallic mercury with constant stirring, and covering to prevent the access of air whenever it inflames from the heat evolved. The red crystalline mass thus produced is known as Vermilion.

403. The SUBIODIDE is a green powder,—the PROTO-^{proto}IODIDE, a brilliant red powder, which is best obtained by mixing together solutions of iodide of potassium and corrosive sublimate.

404. The remaining metals are so rare and so unlikely to fall into the hands of the ordinary student that we may profitably omit their discussion.

405. The quantity of each elementary constituent in a given amount of any chemical compound may be found by the following statement in proportion :—

The atomic weight of the compound : {The atomic weight of any constituent} :: {The given quantity of the compound} : {The required quantity of that constituent}.

Or; if E = the atomic weight or chemical equivalent of the compound.

e = the atomic weight or chemical equivalent of any particular constituent.

W = the weight of the compound in lbs., ozs. or grs.

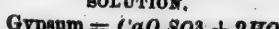
w = the weight of the constituent in question, in lbs., ozs. or grs.

Then $E : e :: W : w$.

$$\text{And therefore } w = \frac{e \times W}{E}$$

EXAMPLE 1.—How many lbs. of sulphur are there in 100 lbs. of gypsum?

SOLUTION.



Therefore the atomic weight $\{ = Ca + S + 2H + 6O = 80$

$$\text{Then } 80 : 16 :: 100 : \frac{16 \times 100}{80} = 13\frac{1}{2} \text{ lbs. Ans.}$$

EXAMPLE 2.—How many grains of each elementary constituent are there in 240 grains of calomel?

SOLUTION.

Calomel is subchloride of mercury = Hg_2Cl .

Atomic weight of 2 equiv. of Hg = 200.

" " 1 equiv. of Cl = 35.5.

Atomic weight of calomel..... 235.5.

$$\text{Then } 235.5 : 200 :: 240 : \frac{200 \times 240}{235.5} = 203 \frac{3}{5} \text{ grs. of mercury.}$$

$$\text{And } 235.5 : 35.5 :: 240 : \frac{35.5 \times 240}{235.5} = 38 \frac{2}{5} \text{ grs. of chlorine.}$$

EXAMPLE 3.—How many pounds of each elementary constituent are there in 180 lbs. of saltpetre?

SOLUTION.

Saltpetre is Nitrate of Potassa = $KO_3NO_3 = K + N + O$.

Atomic weight of 1 equiv. of K = 39.

" " 1 equiv. of N = 14.

" " 6 equiv. of O = 48.

" " of Saltpetre = 101.

$$\text{Then } 101 : 180 :: 39 : \frac{180 \times 39}{101} = 69 \frac{4}{101} \text{ lbs. of Potassium.}$$

$$101 : 180 :: 14 : \frac{180 \times 14}{101} = 24 \frac{96}{101} \text{ lbs. of Nitrogen.}$$

$$101 : 180 :: 48 : \frac{180 \times 48}{101} = 85 \frac{55}{101} \text{ lbs. of Oxygen.}$$

EXERCISE.

1. Give the chemical names of the following compounds:—

HO ; CO_2 ; Al_2O_3 ; NO_4 ; ClO_4 ; $2C_3O$; HO_2SO_3 .

2. Give the symbols of the following compounds:—

Carbonic oxide; hydrocyanic acid; potash; nitrate of soda; saltpetre; silicic acid; gypsum; Epsom salts; apatite; dolomite; permanganic acid; olefiant gas; hydrochloric acid; calomel; cinnabar; selenite; vermillion; red precipitate; corrosive sublimate; hydriodic acid; cyanic acid; ammonia; bleaching powder; carbonate of soda; lime.

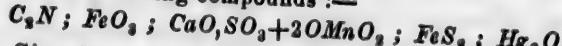
3. Calculate how much of each elementary constituent there is in 100 oz. of each of the foregoing compounds.

4. Given the spec. grav. of mercury vapor 7.000 and its chemical equivalent 100, find its combining volume.

5. Given the spec. grav. of ether vapor 2.586 and its chem. equiv. 37, find its combining volume.

6. Given the spec. grav. of phosphuretted hydrogen 1.240 and its chem. equiv. 35, find its combining volume.

7. Give the chemical name and also the atomic weight of each of the following compounds :—



8. Give the symbols and chemical equivalents of the following compounds :—

Oxalic acid ; laughing gas ; Glauber's salts ; litharge ; light of carburetted hydrogen ; sulphuric acid ; chlorate of potassa ; hydrocyanic acid ; tartar emetic ; red lead.

9. How many pounds of each elementary constituent are there in 250 grs. of each of the foregoing compounds ?

10. Give the general formula of each of the following compounds :—

Protoxide ; bisulphide ; pentoxide ; teriodide ; sulphate ; carbonate ; cyanide ; chlorate ; hyposulphite ; sesquichloride ; sesquichlorate ; nitride ; sulphionide ; sesquicarbonate ; nitrationide ; suboxide ; binoxide ; pentasulphide ; sesquisulphate ; binitrate.

R E A G E N T S .

SULPHURIC ACID.—Frequently rendered impure by presence of lead, arsenic and nitric acid. The lead may be detected by diluting with six or eight parts of distilled water, when, if lead be present, a milkiness is produced by the sulphate of lead, which is only soluble in concentrated acid. When H_2SO_4 is diluted with water, and a stream of HS passed through it, the lead is precipitated as a black sulphide: the arsenic as a yellow sulphide. When a drop or two of solution of indigo in H_2SO_4 is mixed with the suspected acid, the blue color is discharged if nitric acid be present. Or the HO, NO_3 may be detected by the production of a brown dis-coloration on a crystal of sulphate of iron when suspended in the diluted acid.

Pure H_2SO_4 can only be obtained by careful distillation, but for ordinary purposes the sulphuric acid of commerce is sufficiently pure.

NITRIC ACID.—Impurities: *fixed salts*, which remain behind when the acid is evaporated; hydrochloric acid, detected by the formation of a white

precipitate with nitrate of silver; and sulphuric acid, detected by diluting the acid with five times its weight of water, and adding nitrate of barytes, when a white precipitate of sulphate of barytes is thrown down. May be purified by distilling and rejecting the first and last fourths that pass over.

HYDROCHLORIC ACID.—Impurities, SO_3 ; SO_2 ; Cl ; Fe and As . The SO_3 is detected by chloride of barium, which gives a white precipitate of sulphate of barytes. The SO_3 is oxidized by boiling with the addition of NO_3 , and the resulting SO_3 detected as above; the chlorine is detected by its bleaching a solution of indigo when added to the suspected acid; iron, by giving a greenish black precipitate with sulphide of ammonium; arsenic, by precipitation as yellow sulphide upon passing a current of HS through the acid.

TARTARIC ACID ($C_8H_4O_{10} + 2HO$) of commerce is sufficiently pure.—Solution 1 part in 10 of water.

OXALIC ACID ($C_2O_4 + 3HO$) of commerce is sufficiently pure. Solution, 1 part in 16 of water.

ACETIC ACID ($C_4H_4O_3 + HO$).—The liquid acetic acid of commerce is pure enough for most purposes, and is sufficiently strong. (May contain SO_3 , or more rarely SO_2 and HCl .)

ETHER (C_4H_8O) of the shops is sufficiently pure.

ALCOHOL ($C_2H_6O_3$).—Rectified spirit has a specific gravity of 0.88, and contains 14 per cent. of water. Absolute alcohol is obtained from rectified spirit by distilling it, first from caustic lime, and afterwards from ignited carbonate of potassa or anhydrous sulphate of copper.

WATER (HO) for chemical purposes must be carefully distilled.

CHLORINE WATER ($HO + 2Cl$).—Pass chlorine gas into distilled water till saturated. Must be prepared as required.

SULPHURETTED HYDROGEN (HS).—Add hydrochloric acid to protosulphide of iron in a gas-bottle; wash the evolved gas. When a solution of it in water is employed, it should be freshly prepared. The solution ought not to become black on the addition of ammonia, as it will do if iron be present.

CARBONATE OF AMMONIA ($2NH_4O_3CO_2$).—The clear white masses of sesquicarbonate of the shops are chemically pure; dark-colored portions must be rejected. The salt is dissolved in 4 times its weight of cold water, and then mixed with 1 part by weight of liquid ammonia to neutralize the excess of CO_2 .

AMMONIA (NH_3) of commerce is pure; may be diluted with an equal bulk of water.

CHLORIDE OF AMMONIUM (NH_4Cl).—Dissolve the commercial salt in water, add a few drops of sulphide of ammonium, and boil till all odor is lost; when this mixture is filtered from the precipitated sulphide of iron, it consists of a solution of pure chloride of ammonium.

SULPHIDE OF AMMONIUM (NH_4S).—Pass HS into a solution of NH_3 till the liquid produces no precipitate with a solution of MgO, SO_3 .

OXALATE OF AMMONIA (NH_4O, C_2O_4).—Exactly neutralize a solution of oxalic acid by ammonia, and crystallize. The crystals may be dissolved in 24 parts of water.

CAUSTIC POTASSA ($KO.HO$) of commerce is very impure, containing, among other substances, KCl ; $KO.SO_3$; $KO.SIO_3$; $KO.CO_2$; Al_2O_3 , and PbO —the lead and SIO_3 being derived from the flint glass bottles in which the reagent is kept. The commercial salt may be rendered sufficiently pure by dissolving it in *absolute* alcohol, in which its impurities are insoluble. The alcoholic solution evaporated in a silver dish, with careful exclusion of CO_2 , gives perfectly pure $KO.HO$. Preserve in German glass bottles.

IODIDE OF POTASSIUM (KI) of commerce is sufficiently pure for most purposes, but may be separated from $KO.CO_2$ by crystallization from *absolute* alcohol. The solution for reactions consists of 1 part KI in 10 of water.

CYANIDE OF POTASSIUM (KCy) of the shops is sufficiently pure.

FERROCYANIDE OF POTASSIUM (K_3CJy) of the shops is pure. Dissolve in 12 parts water,

FERICYANIDE OF POTASSIUM (K_3CJdy) of commerce is pure enough for analytical purposes. Dissolve in 10 parts water.

SULPHOCYANIDE OF POTASSIUM ($KCyS$).—Fuse 46 parts of K_2CJy + 17 $KO.CO_2$ + 32 of S in a covered iron crucible; allow the fused mass to cool, and then boil it in strong alcohol. The sulphocyanide crystallizes on cooling. Dissolve 1 part in 10 of water.

ACETATE OF POTASSA ($KO.A$) of the shops is sufficiently pure. Dissolve in 4 parts water.

SULPHATE OF POTASSA ($KO.SO_3$).—Re-crystallize the commercial salt, and dissolve in 12 of water.

NITRATE OF POTASSA ($KO.NO_3$).—Re-crystallize the commercial salt and dissolve in 10 of water.

CHROMATE OF POTASSA ($KO.CrO_3$).—Dissolve the commercial salt in 10 parts of water.

CAUSTIC SODA ($NaO.HO$).—Prepare in the same manner as caustic potassa.

ACETATE OF SODA ($NaO.A$) of commerce is sufficiently pure. Dissolve in 4 parts of water. Is cheaper and is used as a substitute for $KO.A$.

CARBONATE OF SODA ($NaO.CO_2$) of commerce is pure enough for all purposes except toxicological investigations.

BIBORATE OF SODA, borax, ($NaO.2BO_3 + 10 HO$).—Re-crystallize the commercial salt. Heat the crystals in a crucible till they cease to swell, and then powder the residue. It is used only in blow-pipe experiments.

PHOSPHATE OF SODA ($2 NaO.HO.PO_5 + 12 HO$), the commercial salt may be rendered sufficiently pure by two or three re-crystallizations. For test solution, dissolve 1 part in 10 of water.

BARYTA WATER is a saturated solution of baryta (BaO). The baryta is best obtained by heating to redness in a crucible 6 parts of finely powdered $BaO.SO_3$ + 1 part of powdered charcoal + $1\frac{1}{2}$ parts of flour. The resulting mass is to be boiled with water for a long time in a flask loosely corked and afterwards filtered while hot with careful exclusion of carbonic acid.

CHLORIDE OF BARIUM ($BaCl$).—Re-crystallize the commercial salt and dissolve in 10 parts of water.

NITRATE OF BARYTA (BaO, NO_5).—Re-crystallize the commercial salt and dissolve in 10 parts of water.

LIME (CaO).—The white pieces of freshly burnt quicklime should be preserved in well-stoppered bottles.

CHLORIDE OF CALCIUM ($CaCl + HO$).—Is prepared by dissolving the finest white marble, or precipitated carbonate of lime, or Iceland spar, in hydrochloric acid, the acid not being in sufficient quantity to dissolve the carbonate of lime.

SULPHATE OF LIME ($CaO, SO_3 + 2 HO$).—Precipitate pure carbonate of lime or chloride of calcium with SO_3 , and wash the precipitate till it is no longer acid. A solution is made by boiling the salt in distilled water, and filtering.

SULPHATE OF MAGNESIA ($MgO, SO_3 + 7 HO$).—Dissolve the commercial salt in 10 parts of water.

IRON (Fe).—The purest iron of commerce is met with as piano-forte wire.

FERROUS SULPHATE ($FeO, SO_3 + 7 HO$).—Dissolve the commercial salt in cold water.

FERRIC CHLORIDE ($Fe_2 Cl_3$).—Dissolve the purest iron in HCl , boiling the solution, and adding NO_5 drop by drop till the greenish-brown color of the solution changes to a bright yellow. The $Fe_2 O_3$ is then precipitated by excess of ammonia, and the precipitate, after thorough washing with hot water, dissolved in HCl , care being taken not to use enough of the acid to dissolve all the ferric oxide.

NITRATE OF COBALT ($CoO, NO_5 + 3 HO$).—Dissolve the commercial salt in 10 parts of water.

COPPER (Cu), in the form of clippings, foil, and wire, should be preserved in well-stoppered bottles.

SULPHATE OF COPPER ($CuO, SO_3 + 5 HO$).—Re-crystallize the commercial salt or dissolve pure copper (obtained by electrolysis), in hot sulphuric acid. Dissolve 1 part of the salt in 10 of water.

ACETATE OF LEAD (PbO, \bar{A}).—Re-crystallize the commercial salt, and dissolve it in 6 parts of water.

NITRATE OF SILVER (AgO, NO_5).—Fuse the pure nitrate (see Art. 387,) and dissolve it in 20 parts of water.

MERCURIOUS NITRATE ($Hg_2 O, NO_5$).—Dissolve pure mercury in cold NO_5 , and keep the solution in a bottle over metallic mercury.

MERCURIC CHLORIDE ($HgCl$).—The commercial salt is sufficiently pure. Dissolve it in 16 parts of water.

PROTOCHLORIDE OF TIN ($SnCl$).—Heat excess of granulated tin with strong HCl , and filter. Place in the bottle containing the clear solution some fragments of granulated tin and some very dilute HCl .

OXIDE OF BISMUTH (BiO_3).—Dissolve metallic bismuth in as small a quantity of NO_5 as possible. Dilute with water. Decant the supernatant fluid. Digest the precipitate with excess of ammonia: filter, wash and dry.

ZINC (Zn).—Should be kept in strips or clippings and also granulated. (The latter variety is obtained by passing the melted metal in a thin stream into cold water.)

MOLYBDATE OF AMMONIA (NH_4O, MoO_3).—Roast the native sulphide of molybdenum in a platinum crucible as long as SO_2 continues to be given off, and dissolve the impure molybdic acid thus obtained in ammonia by the aid of heat. Upon filtering and crystallizing by evaporation, the molybdate is obtained in a state of tolerable purity.

SOLUTION OF INDIGO.—Digest, for several days, powdered indigo in concentrated SO_3 . Dilute with water—allow the mixture to settle, and pour off the liquid from the undissolved and precipitated residue.

SOLUTION OF LITMUS.—Boil litmus in distilled water and keep in an open bottle.

LITMUS PAPER.—Dissolve litmus in water. Dip white writing-paper (not highly glazed) into the solution, dry and cut into narrow slips, which must be preserved in stoppered bottles.

RED LITMUS PAPER.—Proceed as above, having first reddened the blue solution of litmus by the addition of a drop or two of dilute sulphuric acid.

DAHLIA PAPER or PANSY PAPER is made as above, the colored solution being obtained by boiling the petals of the purple dahlia or pansy in alcohol. These papers are more delicate than litmus, and are turned green by alkalies.

TURMERIC PAPER.—Use alcoholic extract of turmeric, as above. The slips are turned reddish-brown by alkalies.

ACETATE OF LEAD PAPER is prepared by dipping the paper into solution of acetate of lead. It is used for the detection of HS .

GELATIN, in the form of isinglass, and **WHITE SUGAR** and **WHITE STARCH**, should be kept in the laboratory.

R E A C T I O N S .

NITRIC ACID.

1. Nitrates are for the most part soluble.
2. Nitrates heated with $KCly$ detonate.
3. Nitrates heated with metallic copper or mercury, or with SO_3 , evolve red fumes.
4. Nitrates in solution bleach solution of indigo in SO_3 .
5. Nitrates added to dilute SO_3 render a crystal of ferrous sulphate brown.

AMMONIA.

1. When free, is distinguished by its pungent odor, and evanescent action on test-paper.
2. Salts of ammonia are volatilized by heat.
3. Salts of ammonia treated with a solution of caustic potassa evolve a pungent and alkaline gas.

1. *Carbonates are decomposed by acids.*
2. *Acid of the displaced acid.*

CARBONIC ACID.

1. Carbonates are decomposed with effervescence by all other acids except HCl .
2. The displaced carbonic acid gas is inodorous, incombustible, a non-supporter of combustion; heavier than air, so that when poured on a flame it extinguishes it as water would do. It renders lime-water turbid.

1. *Oxalic acid is decomposed by acids.*

OXALIC ACID.

1. Oxalic acid or an oxalate heated with SO_3 evolves a mixture of CO_2 and CO .
2. Oxalic acid and its salts precipitate salts of lime, and the precipitated oxalate of lime is insoluble in acetic acid, but it is soluble in HCl .

CHLORINE, OR HYDROCHLORIC ACID.

1. Free chlorine is distinguished by its green-yellow color, its pungent suffocating odor, its bleaching properties, &c.
2. Hydrochloric acid, or chlorides in solution, give a white precipitate with nitrate of silver.

CHLORIC ACID.

1. Chlorates detonate when subjected to friction in contact with sulphur or other combustible bodies.
2. Chlorates are all soluble in water.
3. Chlorates are all converted by heat into chlorides.
4. Chlorates detonate when heated with $KCly$.
5. Chlorates moistened with SO_3 evolve yellow ClO_4 , which is very explosive.
6. Chlorates in solution added to tincture of litmus, upon the addition of a few drops of SO_3 bleach the litmus.

NOTE.—Test 5 and 6 are regarded as most characteristic.

IODINE OR HYDRIODIC ACID.

1. Iodine is distinguished by its beautiful violet colored vapor, its bleaching power, its solubility in alcohol, and in solutions of the alkaline iodides, its odor, the blue color it strikes with starch, &c.
2. Iodine is liberated from iodides by the action of SO_3 .
3. Iodine is precipitated from solution of iodide as a brown powder, by the addition of chlorine or fuming nitric acid.
4. Iodides with AgO, NO_3 , give a yellow precipitate insoluble in NO_3 and in NH_3 .
5. Iodides with acetate of lead give a yellow precipitate, which dissolves in considerable excess of water at 212° , and upon cooling is deposited in golden plates.
6. Iodides in solution do not give blue color with starch till the iodine is liberated by addition of SO_3 or Cl , &c.

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BROMINE, BROMIDES.

1. Free Bromine is recognised by its odor, its color, its great volatility and solubility in water, its bleaching power, and the yellow color it strikes with starch.

2. Bromides, like chlorides and iodides, are soluble in water, sparingly soluble in alcohol, and very nearly insoluble in ether. Bromine is liberated from a bromide in solution, by the careful addition of chlorine, it remains dissolved in the water, and may be separated from this by agitation with ether, which carries it to the surface.

3. Bromine, or bromides in solution, give with AgO, NO_5 , a faintly yellow precipitate, insoluble in boiling NO_5 , but is slowly dissolved by concentrated NH_3 .

CYANOGEN AND CYANIDES.

1. Free cyanogen is distinguished by its odor (like that of bitter almonds), its exceedingly poisonous action on the animal economy, and its burning with a violet flame.

2. Cyanides in solution, cyanogen, or hydrocyanic acid, give with AgO, NO_5 , a white precipitate soluble in NH_3 , and (slowly) in boiling NO_5 , but insoluble in cold NO_5 . The gas cyanogen may be evolved from this cyanide of silver by careful ignition.

3. Cyanides are decomposed by acids, hydrocyanic acid being evolved. This has an almond odor, burns with a blue flame, and is exceedingly poisonous. If mixed with a little NH_4S , and boiled till all odor is destroyed, and the residue treated with Fe_2Cl_3 , a splendid blood red color is produced, owing to the formation of ferric sulphocyanide.

SULPHIDES.

1. Hydrosulphuric acid or sulphuretted hydrogen is recognised by its odor, its poisonous and narcotic properties, its solubility in water to the extent of two volumes, its burning with a blue flame, and the readiness with which it may be made to assume the liquid state by pressure or cold. Also by its precipitating most of the metals from their solutions.

2. Sulphides are, for the most part, insoluble in water; but are soluble in acids; they are also nearly all highly colored.

3. Sulphides, warmed with concentrated SO_3 or HCl , generally give off HS , which is distinguished as above described.

4. Sulphides (insoluble) may be converted into soluble NaS , by fusion with NaO, CO_2 on charcoal. This and all other soluble sulphides give a beautiful violet or purple color, with a dilute solution of nitroprusside of sodium.

SULPHUROUS ACID AND SULPHITES.

1. Free SO_2 is distinguished by its odor; solubility to extent of 50 volumes in water; its bleaching properties; and its deoxidizing effect upon iodic acid, from which it liberates the iodine,—hence it blues test paper prepared by a solution of starch in iodic acid.

2. Sulphites are for the most part (except those of the alkalies) insoluble in water and saline solutions, but are soluble in weak acids.

3. Sulphites heated with SO_3 are decomposed with effervescence and evolution of SO_2 .

4. Sulphites boiled with stannous chloride ($SnCl$) and HCl evolve HS , which may be detected by its blackening the acetate of lead paper.

5. Sulphites are decomposed by the addition of HCl , or any other strong acid; the SO_2 being evolved without the precipitation of sulphur. (Sulphites are thus most easily distinguished from hyposulphites, as strong acids added to the latter evolve SO_2 and precipitate sulphur.)

SULPHURIC ACID AND SULPHATES.

1. Sulphates are for the most part soluble in water; but those of barium mercury, and lead, and a few other metals, are insoluble.

2. Sulphates fused with Na_2CO_3 on charcoal are reduced to sulphides.

3. Sulphuric acid and sulphates do not evolve HS when boiled with a solution of $SnCl$ in HCl .

4. Sulphuric acid and sulphates give white precipitate with BaO, NO_3 or with $BaCl$. The precipitated BaO, SO_3 requires 43,000 parts of water to dissolve it; is sparingly soluble in SO_3 ; and is insoluble in NO_3 and HCl .

5. Sulphuric acid and sulphates give white precipitates with solutions of mercuric or lead salts, and also with solutions of the salts of strontia or lime.

PHOSPHOROUS ACID AND PHOSPHITES.

1. Phosphites (neutral) are, with the exception of those of the alkalies, insoluble in water; but the acid phosphites are soluble.

2. Phosphorous acid and soluble phosphites reduce silver, gold, mercuric and cupric salts, and precipitate the metal, especially upon boiling the mixture.

3. Phosphites in solution are unchanged by being boiled with caustic potassa.

4. Phosphites (dry) heated evolve pure hydrogen; phosphite of lead, however, evolves phosphuretted hydrogen.

PHOSPHORIC ACID AND PHOSPHATES.

1. Phosphates when neutral are (except those of the alkalies) insoluble in water; but many of the acid phosphates, especially those with formula $MO, 2HO, PO_3$, are soluble in water. Most all are soluble in acids.

2. Phosphates or PO_3 give with $CaCl$ a white precipitate, soluble without effervescence in acetic acid.

3. Phosphates or PO_3 give with AgO, NO_3 a yellow precipitate, soluble in NO_3 or in NH_3 .

4. Phosphates or PO_3 agitated with NH_4Cl ; NH_3 or MgO, SO_3 , give a crystalline precipitate soluble in acetic and other acids.

5. Phosphates or PO_3 (the former upon the addition of HCl or NO_3) give a yellow precipitate with molybdate of ammonia. The precipitate may not form immediately, but will do so upon standing for a short time.

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SILICIC ACID.

1. Silicic acid in powder dissolves as an alkaline silicate when boiled with excess of NaO or $NaO.CO_2$.

2. Silicates in solution are decomposed by many acids, as HCl and the silicic acid precipitated. If now this precipitated SiO_3 be removed and dissolved in dilute HCl , and dried perfectly in a water bath, anhydrous SiO_3 remains as a white insoluble gritty powder.

BORACIC ACID.

1. Borates in concentrated solution are decomposed by SO_3 , the boracic acid crystallizing in plates when the solution cools.

2. Boracic acid imparts a green color to the flame of alcohol. If a borate is employed, the addition of SO_3 is necessary in order to set free the BO_3 .

3. Boracic acid acts like an alkali upon turmeric paper; i. e., turns it reddish brown. To apply to test, dissolve the suspected borate in excess of HCl , and apply the test paper.

POTASSIUM. (Solution for reactions, KCl in water.)

1. Salts of K when pure tinge the flame of the blowpipe violet.

2. Salts of K are readily soluble in water, with the exception of the bitartrate and chloroplatinate.

3. Salts of K in rather concentrated solution give, when agitated with solution of tartaric acid, a white crystalline precipitate of cream of tartar, soluble in 60 of water.

4. Salts of K in solution, slightly acidulated with HCl , give with a mixture of $PtCl_4 + HCl$ a yellow crystalline precipitate of chloroplatinate, insoluble in alcohol, but soluble in 144 parts of water.

SODIUM. (Solution for reactions, $NaCl$ in water.)

1. Salts of Na tinge the blowpipe flame yellow. (Only reliable test.)

2. Salts of Na are all soluble, except the acid metantimoniate, which is obtained by adding a freshly prepared solution of metantimoniate of potassa to a solution of a soda salt. This test is difficult of application, and not much used.

CALCIUM. (Solution for reactions, $CaCl$ in water.)

1. Salts of Ca color the flame of a blowpipe red. If a trace of soda be present, the flame will be colored orange.

2. Salts of Ca heated on charcoal before the blowpipe become remarkably incandescent.

3. Salts of Ca in concentrated solution are not precipitated by $CaO.SO_3$ but are partially precipitated by dilute SO_3 or by solution of $KO.SO_3$. The precipitated $CaO.SO_3$ is soluble in 460 parts of water; the solution giving a precipitate of oxalate of lime upon addition of oxalic acid, and of $BaO.SO_3$ on addition of $BaCl$.

4. Salts of Ca are precipitated by solution of C_2O_3 or of $NH_4O.C_2O_3$. The precipitated $CaO.C_2O_3$ is soluble in HCl , but is insoluble in acetic acid.

5. Salts of *Ca* are precipitated by solution of ferrocyanide of potassium as a double ferrocyanide of *K* and *Cl*, which requires 800 of cold water to dissolve it. It is insoluble in *HCl*.

6. Salts of *Ca* are not precipitated by chromic or hydrofluosilicic acids or by solution of hyposulphite of soda.

STRONTIUM. (Solution for reactions, *SrO*, *NO₃*, in water.)

1. Salts of *Sr* tinge the flame of a blowpipe a fine crimson; easily distinguished from the red or orange red of calcium salts.

2. Salts of *Sr* are not precipitated by chromic or hydrofluosilicic acid, or by hyposulphite of soda.

3. Salts of *Sr* are precipitated by sulphuric acid or by soluble sulphates. The sulphate of strontia is soluble in 6900 cold or in 9850 boiling water; is not soluble in nitric acid.

BARIUM. (Solution for reactions, *BaCl* in water.)

1. Salts of *Ba* impart a yellowish-green tinge to the blowpipe flame.

2. Salts of *Ba* give a white precipitate with dilute *SO₃*, or with solution of *CaO*, *SO₃*. The precipitate requires 48,000 parts of water to dissolve it, and is no more soluble in acids or in solutions of *NaCl* or *NH₄Cl*.

3. Salts of *Ba* give with chromate of potassa a pale yellow precipitate, insoluble in water but soluble in most acids.

4. Salts of barium are precipitated by solutions of the carbonates, oxalates, and phosphates.

5. Salts of barium form a white gelatinous precipitate with hydrofluosilicic acid, soluble in 3800 of water, but insoluble in alcohol.

6. Salts of barium are precipitated by hyposulphite of soda.

MAGNESIUM. (Solution for reactions, *MgCl* in water.)

1. Salts of *Mg* are not precipitated by solutions of sulphates or chromates.

2. Salts of *Mg* give a precipitate when boiled with ferrocyanide of potassium, the precipitate being insoluble in *NH₄Cl* but soluble in *HCl*.

3. Salts of *Mg* are precipitated by *KO*, *CO₃*, the precipitate being soluble in solutions of salts of ammonia.

4. Salts of *Mg* give a white crystalline precipitate with soluble phosphates on addition of a little *NH₃*.

ALUMINUM. (Solution for reactions, *Al₂Cl₆* in water.)

1. Salts of *Al* give with caustic *KO* a white precipitate soluble in excess of the alkali.

2. Salts of *Al* give with *NH₃* a white precipitate, nearly insoluble in excess of the precipitant.

3. Salts of *Al* do not color the blowpipe flame; but when intensely heated before the blowpipe, after having been moistened with nitrate of cobalt, they acquire a fine blue color.

ZINC. (Solution for reactions, ZnO, SO_3 in water.)

1. Salts of Zn heated on charcoal with carbonate of soda are reduced, the zinc volatilizing and producing *an incrustation on the charcoal* which is yellow while hot, but white when cold. The oxide moistened with a solution of nitrate of cobalt and strongly heated in the oxidizing flame becomes green.
2. Salts of Zn with NH_3 or KO , give a white precipitate of hydrate of Zn easily soluble in excess of the alkali.
3. Salts of Zn , in alkaline solution, are precipitated *white* by NH_4S ; but not by the chloride. (Zinc is the only metal which forms a white sulphide.)

NICKEL. (Solution for reactions, NiO, SO_3 in water.)

1. Salts of Ni , fused with a borax bead in the *outer* or *oxidizing* flame of the blowpipe yield a yellowish red color, but in the *inner* or *reducing* flame the bead becomes opaque and grey. The addition of a small quantity of nitre changes the color to a reddish purple.
2. Salts of Ni , with caustic KO , give a pale apple-green precipitate of hydrate, insoluble in excess. Ammonia gives a similar precipitate, which is readily soluble in excess, forming a purplish-blue solution.
3. Salts of Ni , with NH_4S , give a black precipitate, nearly insoluble in HCl , but readily soluble in addition of NO_3 .
4. Salts of Ni , with cyanide of K , give green precipitate, soluble in excess of the precipitant, forming a deep amber-colored solution; the cyanide of nickel being reprecipitated by addition of HCl or of SO_3 .
5. Salts of Ni are precipitated green by ferricyanide of K , and reddish-brown by ferricyanide of K .

COBALT. (Solution for reactions, CoO, NO_5 in water.)

1. Salts of Co , fused with a borax bead, give a fine blue glass, either in the outer or the inner flame of the blowpipe.
2. Salts of Co , with caustic KO , give a blue precipitate, which turns green on exposure, and becomes red when boiled.
3. Salts of Co give, with NH_3 , a blue precipitate, which slowly dissolves in excess, forming a reddish-brown solution.
4. Salts of Co give a black precipitate with NH_4S , the solution sparingly soluble in HCl .

COPPER. (Solution for reactions, CuO, SO_3 in water.)

1. Salts of Cu , fused with a borax bead in the *outer* flame of the blowpipe, yield a glass which is greenish-blue when hot, but becomes blue when cold. Exposed to the inner flame this glass either loses its color or becomes tinged with opaque red, according to the quantity of copper which is present.
2. Salts of Cu may be reduced before the blowpipe on charcoal with carbonate of soda.
3. Salts of Cu give, with KO , a light blue precipitate, which becomes dark-brown when heated.

4. Salts of *Cu* give, with *NH₃*, a greenish-blue precipitate, which instantly dissolves in excess, forming a splendid blue or purple solution.

5. Salts of *Cu*, with ferrocyanide of *K*, give a claret-red precipitate, which is insoluble in acids, but readily soluble in *NH₃*, and is decomposed by *KO*. This, the most delicate test for copper, is capable of detecting one part of copper in 1,000,000 of water (Sarzeau).

6. Salts of *Cu*, in acid solution, coat a polished steel needle with metallic copper.

MANGANESE. (Solution for reactions, *MnO₂SO₃* in water.)

1. Salts of *Mn*, fused with a borax bead in the outer blowpipe flame, yield a violet red glass; the color gradually fades in the inner flame, and ultimately disappears.

2. Salts of *Mn*, on platinum wire with carbonate of soda, when heated in the outer flame of the blowpipe give green mass of manganate of soda.

3. Salts of *Mn*, with caustic *KO* or with *NH₃*, give white precipitates, insoluble in excess, quickly becoming brown.

4. Salts of *Mn*, in acid solution, give no precipitate with *HS*, but give an insoluble flesh-colored or buff precipitate with *NH₄S*. The precipitate turns brown on exposure, and is insoluble in acids.

IRON. (Solution for reactions *FeO₂SO₃*, and *Fe₂Cl₃*, in water.)

1. Salts of *Fe*, fused with a borax bead in outer flame of blowpipe, yield a brownish-red glass, which assumes a bottle-green color in the inner flame.

2. Salts of *FeO* give, with caustic alkalies and with *NH₃*, nearly white precipitates, insoluble in excess, which rapidly change in color to greenish and ultimately reddish-brown.

3. Salts of *FeO* give a black precipitate with *NH₄S*. The precipitate is soluble in dilute acids. *HS* gives no precipitate in aqueous solutions of ferrous salts.

4. Salts of *FeO*, treated with ferrocyanide of *K*, give a bluish-white precipitate which rapidly becomes darker, forming Prussian blue. Ferri-cyanide of *K* gives a deep blue precipitate at once with salts of *FeO*.

5. Salts of *FeO*, treated with sulphocyanide of *K*, give no precipitate or change of color if the salt is pure. If any *Fe₂O₃* be present, a red color is at once produced.

6. Salts of *Fe₂O₃*, treated with caustic alkalies or ammonia, give a red-brown precipitate of hydrated sesquioxide, insoluble in excess.

7. Salts of *Fe₂O₃*, treated with *HS*, gives a nearly white precipitate of sulphur, the *Fe₂O₃* being reduced to *FeO*. Sulphide of ammonium gives a black precipitate.

8. Salts of *Fe₂O₃* give a blue precipitate with ferrocyanide of *K*, but give no precipitate with ferricyanide of *K*.

9. Salts of *Fe₂O₃* strike a deep blood-red color with sulphocyanide of *K*, the color disappearing on addition of *HgCl*.

LEAD. (Solution for reactions *PbO₂NO₅* in water.)

1. Salts of *Pb*, fused with *NaO₂CO₃*, in the inner flame of the blowpipe, give a malleable button of lead, and color the charcoal around the outer flame with a yellow incrustation of *PbO*.

2. Salts of Pb give, when treated with caustic alkalies, a white precipitate insoluble in excess.
3. Salts of Pb , with carbonates of KO , NaO , or NH_4O , give insoluble white precipitates.
4. Salts of Pb , with SO_3 , give white precipitate insoluble in NO_8 .
5. Salts of Pb , with NH_4S or with HS , give black precipitate.
6. Salts of Pb , give a bright yellow precipitate with KI , soluble in large excess of boiling water.
7. Salts of Pb , with chromate of potassa, give yellow precipitate soluble in potassa.

TIN. (Solution for reactions $SnCl$ and $SnCl_2$ in water.)

1. Salts of Sn fused on charcoal with cyanide of K in the inner blowpipe flame, give white malleable globules of metallic tin, and a light white incrustation.
2. Salts of SnO treated with KO or with NH_3 give white precipitate soluble in excess of potassa. By boiling this concentrated solution the tin is partly precipitated in metallic state and partly converted into SnO_2 .
3. Salts of SnO in acid solution give a black precipitate with NH_4S or with HS .
4. Salts of SnO treated with $HgCl$ give white precipitate of Hg_2Cl which, after time, if sufficient $SnCl$ be present, is converted into a grey precipitate of metallic mercury.
5. Salts of SnO_2 treated with KO or NH_3 give white precipitate soluble in excess of KO .
6. Salts of SnO_2 treated with HS give bright yellow precipitate which is insoluble in dilute SO_3 or HCl , but soluble in KO , alkaline sulphides, or boiling HCl . Both this and the protosulphide are converted by NO_8 into insoluble binoxide.

CHROMIUM. (Solution for reactions (1) KO, CrO_3 , and (2) Cr_2Cl_3 , in water.)

1. Salts of CrO_3 are all yellow, red, or reddish brown.
2. Salts of CrO_3 in acid solution are reducible by HS , the sulphur being precipitated and the solution changing in color from yellow or red to green.
3. Salts of CrO_3 are reduced to the green sesquichloride of chromium by heating with HCl and alcohol.
4. Salts of CrO_3 in solution are precipitated yellow by acetate of lead.
5. Salts of CrO_3 heated with sulphuric acid and dry $NaCl$ evolve dark red fumes.
6. Salts of Cr_2O_3 impart to a bead of borax an emerald-green color in the outer blowpipe flame, and a yellowish-green color in the inner blowpipe flame.
7. Salts of Cr_2O_3 give with NH_3 a greenish precipitate but slightly soluble in excess, the resulting pink solution being precipitated by boiling.
8. Salts of Cr_2O_3 give with KO a green precipitate readily soluble in excess, the resulting green solution being precipitated by boiling.

BISMUTH. (Solution for reactions, $BiO_3, 3NO_5$ in water.)

1. Salts of *Bi* on charcoal with carbonate of soda yield in the reducing blowpipe flame a globule of metallic bismuth, and color the surrounding charcoal with an incrustation of yellow BiO_3 .
2. Salts of *Bi* treated with *HS* give a black precipitate.
3. Salts of *Bi* are decomposed by a large excess of water, a white basic salt being thrown down, which is insoluble in water or in tartaric acid.

ANTIMONY. (Solution for reactions, $SbCl_3$ in water acidulated with HCl , and KO, SbO_5 in water.)

1. Salts of *Sb* fused with carbonate of soda on charcoal in the reducing flame yield a globule of metal which is very brittle, and may be easily rubbed down to a black powder. If continued in the flame the globule volatilizes, and the charcoal becomes extensively coated with a white incrustation.
2. Salts of *Sb* treated with *KO* or NH_3 give a white precipitate, soluble in excess of *KO*.
3. Salts of *Sb* in neutral solutions are decomposed by excess of water, the basic salt which is precipitated being soluble in tartaric acid.
4. Salts of *Sb* treated with *HS* give an orange-red precipitate insoluble in dilute acids, and nearly so in NH_3 and $2NH_4O, 3CO_2$; soluble in concentrated *HCl*, in *KO*, and in alkaline sulphides.
5. Salts of *Sb* in acid solutions, boiled with copper foil, coat the latter with a grey deposit of metallic antimony.
6. Salts of *Sb* in acid solutions (not containing NO_5) give with metallic zinc a pulverulent deposit of metallic antimony.
7. Salts of *Sb* introduced into a mixture of zinc and dilute SO_3 produce an evolution of SbH_3 , in which the following properties are to be observed:—
 - I. It burns with a greenish-blue flame, and evolves white fumes.
 - II. It imparts a black velvety spot to a piece of white porcelain held in the flame.
 - III. If passed through a narrow glass tube heated at one spot to redness, it deposits a black metallic mirror *immediately* beyond the heated point.
8. Salts of SbO_5 treated with *HS* give no precipitate unless an excess of *HCl* be present, in which case an orange-red penta-sulphide is precipitated. It behaves similarly to SbS_3 .
9. Salts of SbO_5 give no precipitate with *KO* or with $2NH_4O, 3CO_2$.

ARSENIC. (Solution for reactions, AsO_3 and AsO_5 in water.)

1. Salts of *As* heated to redness on charcoal in reducing flame emit a garlic odor.
2. Salts of *As* give no precipitate with *KO* or with NH_3 .
3. Salts of AsO_3 in acid solutions treated with *HS* give a bright yellow precipitate which is insoluble in cold dilute acids, but soluble readily in hot NO_5 , in $2NH_4O, 3CO_2$, in alkalies and in alkaline sulphides. The dry sul-

phide, as obtained above, heated in a glass tube with a mixture of K_2O and Na_2CO_3 , yields a metallic mirror of arsenic.

4. Salts of AsO_3 heated in a tube with charcoal and Na_2CO_3 yields a ring of metallic arsenic.

5. Solution of AsO_3 gives no precipitate with Ag_2NO_3 , as the arsenite of silver is held in solution by the free NO_3^- ; when NH_3 is carefully added a yellow precipitate is thrown down, which is easily soluble in excess of either NO_3^- or NH_3 . (Hume's test.)

6. Solutions of AsO_3 with CuO, SO_3 and NH_3 in the same way gives a yellowish green precipitate, soluble readily in NH_3 or any acid. (Scheele's test.)

7. Solution of AsO_3 mixed with large excess of concentrated solution of KO , and boiled with granulated zinc, evolves AsH_3 , which may be recognised by allowing it to pass on a piece of filter-paper spotted over with solution of Ag_2NO_3 , when, if arsenic be present, the spots assume a purplish black color. (Fleitmann's test.)

8. Arsenic in hydrochloric solution, boiled with clean copper, coats the latter with a steel-grey film of metallic arsenic. (Reinsch's test.)

9. Arsenic introduced into a mixture of Zn and SO_3 evolves AsH_3 , which exhibits the following properties:—(Marsh's test.)

I. It burns with a light blue flame, and evolves dense white fumes.

II. It gives a dark spot similar to that produced by SbH_3 .

III. It gives a metallic mirror in a narrow glass tube under the same circumstances as already described in the case of antimony, but the mirror is rather more remote from the most heated part.

NOTE.—The arsenic spot is distinguished from that of antimony by the following characters:

I. Hypochlorite of soda in solution dropped on the arsenic spot dissolves it, but does not act upon the spot of antimony.

II. A drop of solution of iodate of potassa acts in a similar manner.

III. A drop of NO_3^- is placed on the spot and carefully evaporated to dryness; afterwards a drop of solution of Ag_2NO_3 is placed on it, when if the spot were arsenic there is produced a brick-red coloration of arsenate of silver, but if it were antimony no change of color is noticeable.

The arsenic mirror is distinguished from that of antimony by the following means:

IV. The tube containing the mirror is heated. If arsenical, a garlic odor is perceptible; if antimony, there is no odor.

V. The crystals of oxide which are produced by heating the mirror and which are deposited on the sides of the tube, are examined by a microscope. AsO_3 crystallizes in octohedra, SbO_3 generally in elongated prisms, but sometimes in octohedra.

VI. The crystals are dissolved in a small quantity of water, and Hume's or Scheele's test applied.

VII. The mirror is treated in the same manner as is described in III for the spots.

VIII. The tube containing the mirror is sealed below and plunged into an oil-bath at a temperature of about 500° F. If arsenic, it is volatilized; but if antimony, it remains unchanged.

IX. The tube is gently heated, and dry HS passed through it, when if the mirror be arsenic it turns yellow, if antimony it turns orange red. A stream of gaseous HCl is now passed through the tube, when if sulphide of arsenic it remains unaltered, but if it be sulphide of antimony it disappears.

10. Arsenic acid may be detected by the foregoing reduction-test (4), Reinsch's test (6) and Marsh's test (9).

11. Arsenic acid treated with HS does not give a precipitate except in acid solutions and then not readily. It is commonly reduced to As_3O_3 by the action of SO_2 and then precipitated as As_3S_3 .

12. Arsenic acid gives a brick-red precipitate of arsenic of silver when treated with Ag_2NO_3 . This precipitate is readily soluble in NO_3 and NH_3 .

SILVER. (Solution for reactions, Ag_2NO_3 in water.)

1. Salts of Ag heated on charcoal with Na_2CO_3 give a globule of white malleable metal without any incrustation on the charcoal.

2. Salts of Ag give with KO or with NH_3 a brown precipitate insoluble in KO, but readily soluble in NH_3 .

3. Salts of Ag treated with HCl give a white precipitate of $AgCl$, which becomes violet when exposed to the light. It is soluble in NH_3 , but insoluble in water and in NO_3 .

4. Salts of Ag treated with HS give a black precipitate soluble in boiling NO_3 —with deposition of sulphur.

GOLD. (Solution for reactions, Au_2Cl_3 in water.)

1. Salts of gold in concentrated solution give reddish-yellow precipitate with KO or NH_3 .

2. Salts of Au with HS give a black precipitate insoluble in SO_3 , in HCl, and in NO_3 , but soluble in a mixture of NO and HCl.

3. Salts of Au boiled with C_2O_4 give a precipitation of brilliant metallic gold on the sides of the test-tube.

4. Salts of Au treated with Fe_2O_3 give a fine brown precipitate of metallic gold. The supernatant liquid has a blue color.

5. Salts of Au give a purple-red precipitate or coloration when treated with $SnCl_2$ containing a trace of $SnCl_4$.

PLATINUM. (Solution for reactions, $PtCl_4$ in water.)

1. Salts of platinum in rather concentrated solution acidulated with HCl give with KO or NH_3 a yellow crystalline precipitate soluble in excess.

2. Salts of Pt with $SnCl_2$ give a deep red-brown coloration.

3. Salts of Pt with KI give a nearly black coloration.

MERCURY. (Solution for reactions, Hg_2O, NO_3 , and $HgCl_2$, in water.)

1. A salt of mercury heated in a glass tube with twelve times its weight of dry Na_2CO_3 yields a grey ring of minute globules of metallic mercury.

The minute globules may be made to run together into larger ones by rubbing them with a glass rod.

2. Salts of Hg_2O treated with KO or NH_3 give black precipitates, insoluble in excess.

3. Salts of Hg_2O treated with HCl give a white or slightly yellow precipitate of Hg_2Cl , which is insoluble in water and in cold HCl and NO_5 ; blackened by NH_3 .

4. Salts of Hg_2O treated with HS give a black precipitate insoluble in NH_4S and in concentrated NO_5 , but soluble in KS with separation of metallic mercury.

5. Salts of HgO with KO give a precipitate which passes from brown to bright yellow as the quantity of KO is increased.

6. Salts of HgO give a white precipitate when treated with NH_3 or with $2NH_4O_3CO_2$.

7. Salts of HgO treated with KI give a brilliant scarlet precipitate, soluble in excess.

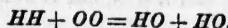
8. Salts of HgO in solutions acidulated with HCl give a brilliant coating of metallic mercury to clean copper foil immersed in the solution.

9. Salts of HgO treated with $SnCl$ give a white precipitate which passes into grey on adding an excess of the reagent.

10. Salts of HgO treated with HS give a precipitate which passes from white to yellow, and becomes successively orange, brownish-red, and finally black, as an excess of the reagent is added. The HgS which is precipitated is insoluble in NO_5 and NH_4S , but is soluble in nitro-muriatic acid and in KS .

APPENDIX I.

In reading continental and certain English works on Chemistry, the junior student is apt to be somewhat confused by the notation adopted, in consequence of the fact that many chemists employ the atomic weights of Gerhardt. In this system the chemical equivalents of oxygen, sulphur, selenium, tellurium, and carbon, are doubled; the others being the same as those commonly employed. Moreover, adopting the binary theory of compounds in the most extended sense of the term, it is assumed that radicals are not truly represented as regards their molecular arrangement when written as *Cl*, or *Cy*, or *H*, their constitution being in reality that of a true salt or binary compound. Hence the body commonly called chlorine is regarded as chloride of chlorine, and is written *ClCl*; that called cyanogen is in fact cyanide of cyanogen, and is written *CyCy*; similarly hydrogen is *HH*; oxygen *OO*; sulphur *SS*; &c. It appears from this that double decompositions are much more frequently met with than was formerly supposed. Thus, when oxygen combines with hydrogen to form water, the reaction is expressed as follows:—



Many arguments are advanced in favor of this theory, one of the strongest being that it, in a manner, explains why the affinities of bodies are so much exalted by the nascent state, as it is very forcibly urged that since the radical has not yet united with itself to form a twin atom, its combining tendency is therefore still wholly unsatisfied.

The following examples of this notation will render these points plain:

Ordinary notation.	Gerhardt's notation.	Ordinary notation.	Gerhardt's notation.
<i>Cl</i>	<i>ClCl</i>	<i>ClO</i>	<i>Cl₂O</i>
<i>HCl</i>	<i>HCl</i>	<i>KOCIO</i>	<i>KClO</i>
<i>KCl</i>	<i>KCl</i>	<i>HS</i>	<i>H₂S</i>
<i>HO,NO₅</i>	<i>HNO₃</i>	<i>KS</i>	<i>K₂S</i>
<i>C₂N</i> or <i>Cy</i>	<i>CNCN</i> or <i>CyCy</i>	<i>HO,SO₃</i>	<i>H₂SO₄</i>
<i>KCy</i>	<i>KCy</i>	<i>KO,SO₃+HO,SO</i>	<i>KHSO₄</i>
<i>KO,CyO</i>	<i>KCyO</i>	<i>KO,SO₃</i>	<i>K₂SO₄</i>
<i>KCyS₃</i>	<i>KCyS</i>	<i>NH₃</i>	<i>H₃N</i>
<i>H</i>	<i>HH</i>	<i>PH₃</i>	<i>H₃P</i>
<i>HO</i>	<i>H₂O</i>	<i>3HO,PO₅</i>	<i>H₃PO₄</i>
<i>KO,H₂O</i>	<i>KHO</i>	<i>KO,2HO,P₂S₅</i>	<i>KH₂PO₄</i>
<i>KO</i>	<i>K₂O</i>		

APPENDIX II.

Information is often sought by beginners in Chemistry as to the nature and cost of the apparatus required for such simple experiments as they may find necessary for the illustrations of the subject. The following list will be found to contain all that is really essential; but it must be borne in mind that the student, by a little ingenuity, can make very much of the apparatus for himself. The cost is given as nearly as it could be ascertained. Full information with regard to making and using chemical apparatus will be found in *Williams' Chemical Manipulations*, a book which ought to be in every student's hands, and which can be had at a cost of about \$4.50.

LIST OF APPARATUS.

A Spirit Lamp,	.....	cost say, \$0.50
Retort Stand,	.....	" 0.50
2 doz. assorted Test Tubes,	.....	" 1.00
A few Florence Flasks or small Retorts,	.....	" 1.00
A few Porcelain Dishes and Capsules,	.....	" 1.00
A Few Watch Glasses,	.....	" 0.50
A Test Tube Stand,	.....	"
Wire Triangles to support crucibles,	.....	Can be made
Wire Rings covered with cloth to support hot retorts, ..	.....	by the Student.
A Pneumatic Trough can be made out of a pail.	.....
2 lbs. Quill Glass Tubing,	.....	cost say, \$1.00
2 lbs. large Glass Tubing,	.....	" 0.75
1 gross Corks,	.....	" 0.40
Several pieces Vulcanized India Rubber Tubing,	.....	" 0.75
1 Nest Hessian Crucibles,	.....	" 0.20
A few Beakers or ordinary Tumblers,	.....	"
A few Precipitating Jars or ordinary Wine Glasses,	.....	"
2 pint, 2 quart, and 2 half-gallon wide-mouth Glass Jars, with ground-glass stoppers, for collecting gases,	.....	" 1.00
6 Quart Bottles with ground-glass stoppers, for acids and liquids,	.....	"
6 Pint do. do. do.	.....	" 0.75
1 doz. two oz. wide-mouthing bottles, with corks,	.....	" 0.50
2 doz. four oz. do. do. do.	.....	" 0.40
. doz. eight oz. do. do. do.	.....	" 0.80
		" 1.00
REAGENTS, &c.		
1 lb. Black Oxide of Manganese,	.....	" 0.20
½ lb. Chlorate of Potassa,	.....	" 0.37½
1 oz. Phosphorus, and bottle,	.....	" 0.10
½ lb. Brimstone,	.....	" 0.05
2 lbs. Sulphuric Acid,	.....	" 0.10

2 lbs. Nitric Acid,.....	cost say, \$0.30
2 lbs. Hydrochloric Acid,.....	" 0.20
2 lbs. Ammonia,.....	" 0.30
1 lb. Zinc Clippings,.....	" 0.10
4 oz. Oxalic Acid,.....	" 0.15
4 oz. Sulphate of Magnesia,.....	" 0.08
1 oz. Litmus,.....	" 0.05
1 oz. Iodine,.....	" 0.25
1 oz. Nitrate of Silver (crystallized),.....	" 1.00
1 oz. Baryta,.....	" 0.10
8 oz. Chloride Ammonium,.....	" 0.20
4 oz. Carbonate Potash,.....	" 0.10
8 oz. Carbonate Soda,.....	" 0.15
Fragments of Marble, or Chalk,.....	"
4 oz. Acetate Lead,.....	" 0.20
4 oz. Bichromate Potassa,.....	" 0.15
4 oz. Ferrocyanide of Potassium,.....	" 0.20
1 oz. Indigo,.....	" 0.10
1 lb. Copper clippings,.....	" 0.05
4 oz. Nitrate Potassa,.....	" 0.10
1 oz. Iodide Potassium,.....	" 0.40
1 oz. Corrosive Sublimate,.....	" 0.10
1 lb. Metallic Mercury,.....	" 1.00
4 oz. Sulphate Iron,.....	" 0.05
A little Lime,.....	"
2 oz. Tartaric Acid,.....	" 0.10
1 oz. Caustic Potash,.....	" 0.10
2 oz. Caustic Soda,.....	" 0.10
2 oz. Chloride Barium,.....	" 0.15
2 oz. Borax,.....	" 0.10
4 oz. Alum,.....	" 0.05
4 oz. Sulphate Copper,.....	" 0.05
1 lb. fluid Acetic Acid, and Bottle,.....	" 0.20
1 gal. Alcohol,.....	" 0.25
1 lb. Ether,.....	" 0.25

APPENDIX III.

LIST OF WORKS ON CHEMISTRY.

1. Fowne's Chemistry for Students, pp. 655.
2. Gregory's Hand-Book of Inorganic Chemistry, pp. 355.
3. Gregory's Hand-Book of Organic Chemistry, pp. 535.
4. Graham's Elements and Applications of Inorganic Chemistry, pp. 852.
5. Abel & Bloxham's Hand-Book of Chemistry,—Theoretical, Practical and Technical, pp. 681.

APPENDIX.

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6. Northcote & Church's Manual of Qualitative Analysis, pp. 423.
 7. Williams' Chemical Manipulations, pp. 580.
 8. Otto on the Detection of Poisons, pp. 178.
 9. Parnell's Chemical Analysis, pp. 520.
 10. Fresenius' Analytical Chemistry, 2 vols., pp. 990.
 11. Odling's Course of Practical Chemistry.
 12. Noad's Chemical Manipulations, pp. 367.
 13. Bowman's Practical Chemistry, pp. 303.
 14. Lehman's Physiological Chemistry, 2 vols., pp. 1195.
 15. Bowman's Medical Chemistry, pp. 288.
 16. Knapp's Chemical Technology, pp. 936.
 17. Kane's Elements of Chemistry, pp. 704.
 18. Solly's Syllabus of Chemistry, pp. 198.
 19. Leibig's Animal Chemistry, pp. 173.
 20. Leibig's Agricultural Chemistry, pp. 400.
 21. Johnston's Lectures on Agricultural Chemistry, pp. 707.

~~12~~ The general student will be best served by Nos. 1, 3, 4, 5, 6, 7, and 16
 of the above-named works.

THE END.